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Sustainability of Water, Sanitation, and Hygiene (WASH) in Post-Emergency Contexts: A Conceptual Framework

Hala Al-Hamawi [1,*], Philip A. Davies [2], Mohammad Mayouf [3] and Anastasia Nikologianni [4]

[1] School of Social Sciences, Nottingham Trent University, Nottingham NG1 4FQ, UK
[2] School of Engineering, University of Birmingham, Birmingham B15 2TT, UK; p.a.davies@bham.ac.uk
[3] College of the Built Environment, Birmingham City University, Birmingham B5 5JU, UK; mohammad.mayouf@bcu.ac.uk
[4] College of Architecture, Birmingham City University, Birmingham B5 5JU, UK; anastasia.nikologianni@bcu.ac.uk
* Correspondence: hala.al-hamawi2022@my.ntu.ac.uk

Abstract: In refugee camps, Water, Sanitation, and Hygiene (WASH) services are essential for health and well-being, yet they face sustainability challenges in post-emergency contexts. Despite considerable research on WASH services in urban and rural areas, a gap exists in addressing sustainability within refugee camps. This study fills that gap by proposing a framework for evaluating WASH system sustainability in such settings. Through a convergent mixed methods research design, sustainability dimensions, metrics, and indicators were first identified via a literature review. These were then validated through expert interviews. The study applies a five-dimensional FIETS (financial, institutional, environmental, technical, and social) framework to assess WASH sustainability. Findings reveal that financial sustainability is the most critical dimension, followed by institutional, technical, social, and environmental factors. The research also identifies key challenges such as limited funding, political barriers, and limited water resource availability. It underscores the importance of coordinated efforts among stakeholders to overcome these obstacles and achieve long-term sustainability. This framework provides a structured approach for practitioners and policymakers to assess and improve WASH services in refugee camps, contributing to broader discourse on sustainable development and water resource management.

Keywords: WASH; sustainability; refugee camps; post-emergency

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1. Introduction

Millions of people have been forced to abandon their homes and settle in refugee camps as a result of both natural and human causes [1,2]. This research focuses on the post-emergency scenario, which is defined as the period of 2 to 25+ years or "the period six months after population movement has stabilised up to the period a durable solution has been reached and the population is no longer displaced" [3]. Although refugee camps were originally intended and planned as temporary solutions, many have persisted for years, sometimes even decades [4]. Sustainable development aims to fulfil today's needs without sacrificing those of future generations [5]. Therefore, this study aims to provide a conceptual framework to support evaluating the sustainability of Water, Sanitation, and Hygiene (WASH) services and an understanding of the challenges associated with sustaining WASH services within post-emergency contexts.

In discussions about WASH, it is essential to emphasise that water is central to achieving the Sustainable Development Goals (SDGs), especially SDG-6 [6,7], as well as promoting

human rights and contributing to socio-economic development [8,9]. The literature presents numerous studies on water and sanitation sustainability, covering both developing and developed contexts across urban and rural settings [10–14]. However, relatively little attention has been paid to refugee camps, especially in the context of post-emergency. While some studies (e.g., [8,11,12]) provide valuable insights, they often fail to address the unique challenges and complexities of ensuring sustainable WASH services in refugee camps. This gap highlights the critical need to explore aspects such as the integration of political dimensions, the establishment of long-term financial mechanisms, and the interplay between the FIETS dimensions in these settings.

There are two prevalent guidelines for managing WASH services in refugee camps. First, the Sphere handbook for minimum standards is instrumental during the emergency phase of humanitarian responses [4,15,16]. Second, the United Nations High Commissioner for Refugees (UNHCR) WASH manual provides guidance principles, minimum standards, and indicators for the various stages of humanitarian responses [3]. However, the evaluation of WASH in post-emergency contexts is currently not fully addressed, creating a gap in the literature. This lack of understanding can limit efforts to improve sustainability and development. Despite the existence of WASH sustainability tools, such as in Refs. [17–19], the complexity of humanitarian settings and the trade-offs between the sustainability of services and other principal challenges (e.g., fund viability, political will) make it difficult to provide and assess sustainable WASH services. Consequently, this study aims to critically assess the sustainability of WASH services in post-emergency settings and address associated challenges.

2. Background

2.1. Sustainability Tools and Dimensions for WASH System

The three pillars of sustainable development include economy, society, and environment [20–22]. Various tools have been developed and applied to evaluate the sustainability of water services, as well as sanitation and hygiene services, using various sustainability dimensions and indicators across different contexts (i.e., urban and rural) but not in post-emergency refugee camps. One widely applied tool is the United Nations Children's Fund (UNICEF) sustainability check, which can be used to assess WASH sustainability in urban and rural areas, schools, and healthcare centres [18]. UNICEF's tool has different dimensions (e.g., functionality, accessibility, availability, affordability, quantity, and quality). Another global WASH sustainability tool, the so-called Sustainability Index Tool, was subsequently developed [19]. The tool is based on five factors: financial, institutional, environmental, technical, and management and can be applied in urban and rural contexts. Among the several dimensions used to assess the sustainability of WASH, many scholars used the FIETS model but did not necessarily include all dimensions. Table 1 illustrates eight studies that assessed WASH-related services, only highlighted in grey, that used FIETS dimensions.

Table 1. WASH-relevant sustainability tools in literature.

Reference	Year	Context	Sustainability Dimensions (Weights)	Application	Application Place
[10]	2005	Urban	- Environmental - Economic - Engineering - Social (no weighting system)	Water facility	City of Toronto, Canada

Table 1. *Cont.*

Reference	Year	Context	Sustainability Dimensions (Weights)	Application	Application Place
[23]	2008	Urban and Rural	- Financial (5%) - Institutional (20%) - Social/Environmental (25%) - Technical (50%)	Community-based Water Projects	Nepal
[11] adopted from Ref. [23]	2008	Rural	- Financial (5%) - Institutional (20%) - Social/Environmental (25%) - Technical (50%)	Water facility	Swaziland
[12]	2014	Rural	- Financial (10%) - Institutional (10%) - Social (40%) - Technical (30%) - Sanitation (10%)	WASH facilities	Mozambique
[24]	2014	Rural	- Financial (10%) - Institutional (20%) - Environmental (10%) - Technical (50%) - Social (10%)	Community-based adaptation-watershed	Blue Nile Highlands of Ethiopia
[13]	2015	Urban	- Place - Permanence - Persons	WASH services	Salta, in northern Argentina
[25]	2018	Rural	- Financial - Institutional - Environmental - Technical - Social - Scoring is on indicators level	Water facilities	Ethiopia
[14] based on Ref. [19]	2019	Urban and Rural	- Financial (35%) - Institutional (20%) - Environmental (15%) - Technical (10%) - Social (20%)	Water facilities	West Africa
[22]	2022	Rural	- Environmental - Economic - Social - Several weighting models	Community-based Water Supply Projects	Rajshahi in Bangladesh

Scholars such as Refs. [12,14,24,25] have utilised the FIETS (financial, institutional, environmental, technical, and social dimensions) tool, asserting that these provide a comprehensive framework for assessing sustainability. A recent study assessed five sustainability tools for a rural water supply developed by various organisations, including the Dutch Water Alliance, International Water and Sanitation Centre International Water and Sanitation Centre (IRC WASH), WaterAid, United States Agency for International Development (USAID), and the World Bank, against the FIETS framework [26]. The evaluation revealed that, among these tools, only those developed by the World Bank and IRC WASH did not comprehensively address all FIETS dimensions. Although FIETS has garnered scholarly attention due to its capacity to predict or understand the likelihood of sustainability, it is important to recognise that the indicators within each dimension can vary. The weight as-

signed to each sustainability dimension reflects its perceived significance and influence on overall sustainability [27]. The literature presents differing perspectives on the importance of each dimension, which is evident in the varied weighting and scoring systems used to evaluate sustainability outcomes, as seen in Table 1.

Godfrey et al. [12], in a study on the sustainability of a WASH program in Mozambique from 2008 to 2012, observed an increase in sustainability from 57% to 80%, primarily due to improvements in the institutional and financial dimensions. This study underscored the critical role these two dimensions play in the overall sustainability of such services. Subsequent research [14] adopted the Rotary-USAID Sustainability Index Tool to develop a framework tailored to the context of West Africa using the FIETS dimensions. Their findings revealed significant inter-correlations among the FIETS dimensions, with financial, institutional, and social dimensions exerting considerable influence on the technical and environmental dimensions. Yet, the Rotary-USAID (2013) did not provide a weighting system for their dimensions to avoid bias toward any specific dimension.

Conversely, when Godfrey et al. [12] aggregated weights based on expert opinions, they arrived at the following distributions: social (40%), technical (30%), financial (10%), institutional (10%), and sanitation (10%). Panthi et al. [23] similarly assigned the highest scores to the technical and social–environmental dimensions, while the financial and institutional dimensions received the lowest. These discrepancies may be attributed to the differing contexts in which sustainability is assessed, affecting the weighting scales employed.

In reviewing 25 sustainability tools for WASH services, Godfrey et al. found that many incorporated FIETS dimensions [12]. While interpreting sustainability in operational contexts remains challenging, Sahely et al. [10]—through evaluating WASH sustainability using the FIETS dimensions as an inclusive approach—demonstrated its effectiveness in the development context. Sustainable services are recommended in emergency and long-term settings [4], but guidance for planning refugee camps is still lacking [28]. There is a gap in guidelines for sustainable WASH delivery, as few attempts have been made to develop comprehensive frameworks in different settings. The following section explores each dimension and its importance.

2.2. Unpacking FIETS

Among the FIETS dimensions, the financial aspect in humanitarian settings is crucial, as financial aid is typically reliant on donor funding and not always guaranteed [29,30]. A comparison between water and sanitation trucking delivery models during emergency response and network delivery models has highlighted the need to study sustainability options and analyse financial expenditures [30]. Although piped networks are more expensive than trucking services, it is a recommended technical approach for post-emergency responses [3]. Such studies underline the importance of shifting services from a 'life-saving' model to a business-oriented one in post-emergency settings and developing customised tools to assess the sustainability of WASH services [31]. This is because many refugee camps remain longer than expected and enter the post-emergency phase. Thus, financial sustainability is essential.

Institutional factors also play a vital role in developing and maintaining sustainable services [29]. The clarity of roles and responsibilities among service beneficiaries, authorities, and suppliers reflects a greater likelihood of institutional sustainability and has been used to evaluate water supplies in West Africa [14]. Institutional strength and capacity are also core indicators [13]. Researchers have proposed various factors to measure institutional sustainability, likely due to the diverse contexts in which sustainability is evaluated, influencing the choice of indicators.

Regarding environmental sustainability, a study in Jordan found that significant pressure on water and sanitation services, resulting from the influx of refugees, negatively impacted the availability of natural resources [32]. Consequently, water scarcity has become severe [33,34], a concern raised by governments in Jordan and Lebanon; both countries have hosted a significant number of Syrian refugees for almost a decade [35]. Therefore, meeting current community water demands must be balanced with sustainable practices to prevent resource depletion and ensure long-term availability [24], making environmental assessments critical for the sustainability of WASH.

Technical sustainability can be achieved by utilising appropriate technologies [36]. There is a need to design and construct water and wastewater facilities that are flexible, adaptive, and robust [37]. The functionality and performance of these facilities, such as the age of infrastructure, are key indicators of technical sustainability [10]. Thus, well-constructed and adaptable infrastructure, coupled with technologies that support long-term operation and maintenance, are essential characteristics of sustainable services.

Social impact is another critical dimension, with WASH services shown to improve the well-being of Syrian refugees and reduce poverty among refugees in Lebanon and Jordan [29]. Multiple indicators have been used to assess the social dimension, including accessibility to water and sanitation [10,33], access to rights and information, community participation, and the prevalence of waterborne diseases [13,37]. This variety of indicators highlights the complexity of evaluating social sustainability, yet it is key to achieving the overall sustainability of services. While some studies have focused on WASH services in refugee camps, they lack a more holistic insight into sustainability, particularly on how this is being measured in the context of refugee camps.

2.3. Sustainability of WASH System in Post-Emergency Context

The need for sustainability in WASH service delivery remains a critical issue, particularly in post-emergency contexts where challenges are heightened. Despite increasing efforts to incorporate sustainability into WASH programming, there is a lack of consensus on effectively achieving this in complex, post-crisis environments. Incorporating sustainability into humanitarian WASH programmes presents significant challenges [38]. While the importance of sustainability is recognised, it is often inadequately reflected in the planning and design of WASH interventions, as well as WASH strategies and guidance. Humanitarian response needs to improve interventions in WASH programmes by adopting sustainability plans [39].

WASH services in post-emergency contexts can offer lasting benefits to affected communities. Such services not only provide immediate relief but also enhance the resilience of WASH services, particularly in protracted crises, enabling them to better absorb and adapt to new shocks [40]. Despite the growing recognition of the importance of sustainability in WASH programmes, there are still significant gaps, particularly the need for a standardised framework for post-emergency contexts, including refugee camps.

3. Methodology and Data

To address the complexity of research in post-emergency contexts, this study employs a mixed methods approach grounded in inductive reasoning [41]. Figure 1 represents the methodological framework of this study, comprising two phases of data collection and analysis. Specifically, convergent mixed-method research is deployed in this study to provide a more efficient synthesis of qualitative and quantitative outputs. While quantitative research allows building upon existing hypotheses and numerical relevant data [42], qualitative research allows in-depth exploring of a complicated situation, which is appropriate for the scope investigated in this research [43]. Secondary data relevant to sustainability dimen-

sions and indicators from the literature are both qualitative and numerical. Ninety-two indicators were extracted, mapped, and analysed from five research studies and two tools developed by organisations. A similar mapping approach was conducted by Ref. [21]. We grouped the indicators using the FIETS tool, which supported narrowing the indicators down to 30. The chosen metrics (details in Table 2) supported the constitution of the conceptual framework (details in Section 5) that enables a more structured and holistic understanding of Sustainability Indicators (SIs) when explored in post-emergency contexts.

As for the primary data, structured interviews with ten high-level WASH experts were conducted [44]. The input of experts is essential, as is their involvement in validating analyses, weighting, and aggregating indicators for achieving robust sustainability outcomes [27]. Specific criteria were used to select participants to ensure the depth and relevance of insights. Participants were selected based on several criteria: (1) they must be senior professional WASH experts with more than ten years of extensive experience in the post-emergency context and knowledge of sustainability; (2) have worked in multiple countries, operating in refugee camps, including post-emergency contexts; (3) have worked across multiple phases of programs or projects. A snowballing approach was used to identify participants with relevant expertise.

The inclusion of 10 interviewees is justified on the basis of their significant expertise and the qualitative nature of this study, where depth of insights is prioritised over numerical breadth. This aligns with prior research norms indicating that smaller, focused samples can yield sufficient data, particularly when participants share highly relevant experiences [45,46]. The diverse backgrounds of these experts ensured a comprehensive perspective, addressing the specific and under-researched challenges of WASH sustainability in refugee camps—a context that prior studies, such as those by the World Bank [29] and de Bakker [30], have not thoroughly explored in the post-emergency phase.

The interviews were structured (standardised) and included a combination of open-ended and closed-ended questions [47]. This approach enabled the collection of both qualitative insights and quantitative scoring data. Open-ended questions explored challenges, sustainability metrics, and strategic actions, while closed-ended questions facilitated the scoring of FIETS dimensions. Interviews were conducted over nine days, averaging 31 min in duration, and were conducted virtually due to participants' geographic diversity. All interviews were conducted in English, recorded, and transcribed. Open-ended responses were analysed using thematic analysis, following Braun and Clarke's six-step framework, which included coding data, grouping codes into themes, and validating these themes against the study objectives. Unlike prior studies, which often rely on generalised WASH data, this study integrates expert-driven insights to contextualise sustainability within the nuanced realities of refugee camps. Section 4.4 presents the key themes identified through this analysis, reflecting systematically derived insights rather than an ad hoc compilation. Quantitative scoring results were analysed using statistical methods. Further details on the analysis and results are presented in Section 5.

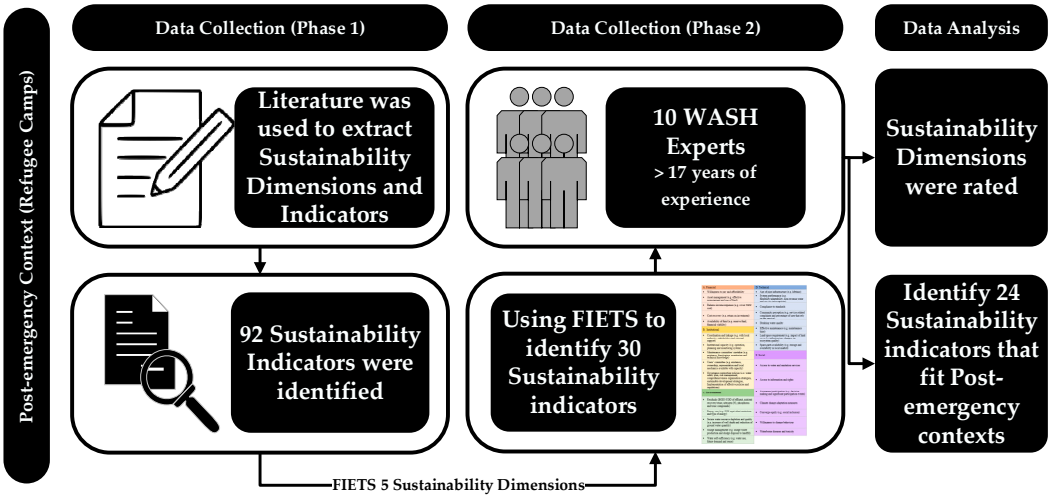

Figure 1. Methodological framework for this research study.

Table 2. Proposed sustainability dimensions and metrics.

Dimension/Metrics
A. Financial
• Willingness to pay and affordability
• Asset management (i.e., effective management and use of funds)
• Balance income/expenses (e.g., cover O&M cost)
• Cost recovery (i.e., return on investment)
• Availability of funds (i.e., reserve fund, financial viability)
B. Institutional
• Coordination and linkage (i.e., with local authority, stakeholders and external support)
• Institutional capacity (i.e., operation, planning and monitoring system)
• Maintenance committee/caretaker (i.e., existence, functioning, monitoring and technical knowledge)
• Users' committee (i.e., existence, ownership, representation and local mechanics available with capacity)
• Governance supporting policies (i.e., water safety plan, risk management, comprehensiveness organisation strategies, sustainable development strategies, Implementation of effective policies and regulations)
C. Environmental
• Residuals (Biochemical Oxygen Demand (BOD_5)/Chemical Oxygen Demand (COD) ratio of effluent, nutrient recovery/reuse, Nitrogen (N), phosphorus and toxic compounds)
• Energy use (i.e., Carbon Dioxide (CO_2) equivalent emissions and type of energy)
• Secure water resource depletion and quality (i.e., increase in well depth and reduction of groundwater quantity)
• Sludge management (i.e., sludge waste production and sludge disposal to landfill)
• Water self-sufficiency (i.e., water use, future demand and reuse)

Table 2. *Cont.*

Dimension/Metrics
D. Technical
• Age of pipe infrastructure (i.e., lifetime)
• facility performance (i.e., flexibility/adaptability, non-revenue water and service interruptions)
• Compliance with standards
• Community perception (i.e., service-related complaints and percentage of users that rely on the service)
• Drinking water quality
• Effective maintenance (i.e., maintenance time)
• Land/space requirement (i.e., the impact of land cover by infrastructure changes on ecosystem quality)
• Spare-parts availability (i.e., storage and availability in the local market)
E. Social
• Access to water and sanitation services
• Access to information and rights
• Awareness/participation (i.e., decision-making and significant participation events)
• Climate change adaptation measures
• Converge equity (i.e., social inclusion)
• Willingness to change behaviour
• Waterborne diseases and toxicity

Note: Background shading has been incorporated to enhance visual clarity and improve interpretability of the data presented.

4. Results

The proposed conceptual framework for the sustainability of WASH consists of a set of dimensions, metrics, indicators and a weighting system for dimensions. This initial framework was developed based on data collection and analysis from Phase 1, which included a comprehensive literature review. The framework is grounded in the FIETS, financial, institutional, environmental, technical, and social dimensions, which are widely used to assess WASH's sustainability in several studies, including in Refs. [14,23–25,48]. Therefore, the FIETS dimensions serve as the pillars for the proposed sustainability framework. Under each dimension, a set of metrics was formulated by grouping SIs (Sustainability Indicators). The term "metrics" refers to a collective of indicators [49]. In this study, SIs were extracted and analysed from various studies and reports [12,13,18,19,21,23,25,50]. Setting SIs by mapping existing indicators to assess sustainable development is a widely accepted approach [51]. A total of 92 SIs were correlated to the FIETS dimensions, then systematically analysed and categorised into three categories: explicitly mentioned as indicators, implicitly contained within an indicator, or neglected due to their lack of relevance. Subsequently, 30 groups of indicators, presented in Table 2, are proposed for inclusion in the framework.

The process of narrowing down the indicators to 30 key metrics involved a multi-step approach. First, the indicators were grouped based on thematic alignment with the FIETS dimensions. Second, relevance to post-emergency contexts was evaluated through expert consultation, with indicators explicitly mentioned in the literature given priority over implicit or less relevant ones. Finally, indicators were assessed for practicality, measurability, and their potential impact on sustainability outcomes. Indicators that lacked direct applicability to refugee camp settings or were redundant across dimensions were excluded.

This systematic process ensured that the final set of metrics was both comprehensive and contextually relevant.

Both the indicators and metrics underwent a second round of validation in terms of their importance and relevance to post-emergency contexts. Through this additional validation step, conducted by experts, the final significant metrics for the sustainability of WASH were identified; these are elaborated in detail in Section 5.

Given the nature of the research, formal IRB approval was not required as no sensitive personal information was collected, and expert participants provided consent in alignment with standard professional research. Experts are given a code combination of abbreviation of interview (IN) and number from 01 to 10, for instance, Expert (IN,01), to anonymise responses. Moreover, specific information was excluded from the analysis to maintain the confidentiality of persons and organisations.

4.1. Participants' Background and Expertise

The participating experts represented a diverse range of organisations, including four staff members from United Nations (UN) agencies, two from International Non-governmental Organisations (NGOs), two from local authorities, and two consultants working at various levels (e.g., national, regional, and multi-regional). These high-level experts bring extensive experience to WASH, with professional backgrounds spanning 17 to 40 years. They have been actively engaged in refugee camps across several countries, including Bangladesh, Ethiopia, Jordan, Lebanon, Pakistan, Sri Lanka, Syria, Tanzania, Uganda, and the West Bank. As a result, they possess both national and international expertise in post-emergency settings. More importantly, they have a rich knowledge of refugee camps and other relevant stakeholders.

The experts' approaches to sustainability in WASH programs are noteworthy. For example, Experts (IN,01) and (IN,07) developed response plans for refugees and assessed the impact of refugee influxes on water resources in Jordan. In contrast, Expert (IN,03) contributed to designing financially sustainable solutions in the Jalozai camp in Pakistan. Expert (IN,05) focused on exploring alternative management models in various refugee contexts and conducted two sustainability audits: one in Bangladesh, which faced political challenges, and another in Algeria, which led to the development of a combined strategy for the sector, now integrated into the country's five-year plan. Additionally, Expert (IN,06) provided guidelines on water supply, sanitation, and sustainability for service delivery agencies, while Expert (IN,08) ensured the adoption and implementation of these guidelines within WASH programs. The interviewed WASH experts have served in multiple countries and addressed sustainability at various stages of WASH programming, including preparation, planning, implementation, and Monitoring and Evaluation (M&E). Their extensive experience offers valuable insights into sustainable practices in diverse post-emergency contexts.

4.2. Sustainability of WASH Framework Rating

Building upon the initial sustainability framework developed in Phase 1 of data collection and analysis, professional experts contributed to validating the key metrics necessary for assessing the sustainability of WASH in post-emergency contexts within refugee camps. Experts were asked to rate the importance of the proposed 30 metrics (as presented in Table 2) that align with the FIETS dimensions for the sustainability of WASH, using a scale from one (unimportant) to four (very important). Out of the 30 metrics, 24 were rated as very important by five or more experts. Based on this analysis, the following metrics were identified as less critical: cost recovery (i.e., return on investment), residuals (BOD_5/COD of effluent, nutrient recovery/reuse, nitrogen (N), phosphorus and toxic

compounds), energy use (i.e., CO_2 equivalent emissions and type of energy), age of pipe infrastructure (i.e., lifetime), land/space requirements (i.e., the impact of land cover by infrastructure changes on ecosystem quality), and climate change adaptation measures.

The consensus among experts regarding the most important metrics underscores their critical role in achieving sustainability in WASH programmes. For instance, there was unanimous agreement on the significance of access to water and sanitation. Additionally, nine experts concurred on the importance of metrics such as the availability of funds, compliance with standards, and secure water resources. Furthermore, eight experts agreed on the relevance of asset management, balancing income and expenses, coordination and linkage, facility performance, water quality, and the presence of waterborne diseases and toxicity. These findings suggest that these highly rated metrics serve as key SIs in WASH services.

Specific examples from the expert interviews further expanded on these findings. For instance, Expert IN,06 stated, "Donor fatigue remains a significant obstacle, particularly in protracted crises where long-term funding commitments are rare". Expert IN,05 highlighted, "Engaging local authorities in Jalozai camp was essential to achieving coordination and ensuring the success of water management systems". Expert IN,01 added, "Groundwater depletion in Jordan underscores the critical need for alternative water sources and sustainable management strategies".

While these agreements reflect a broad consensus, it is important to acknowledge the potential biases in expert perspectives. Some experts provided justifications for rating certain metrics as unimportant. For example, Expert (IN,04) considered the availability of funds for purchasing spare parts more critical than the availability of spare parts in the local market. Similarly, Expert (IN,03) suggested that cost recovery could be deprioritised when focusing on the more important metrics identified for post-emergency contexts. These insights reflect the varied practical experiences of the experts and highlight that certain metrics may hold less importance in post-emergency settings.

4.3. Scoring FIETS Dimensions

As previously discussed, assigning weights to the dimensions reflects their relative importance. There are three common methodologies for weighting indicators: "(1) equal weighting, (2) statistic-based weighting, and (3) public/expert opinion-based weighting" [27]. Given the contextual specificity of post-emergency settings in refugee camps and in accordance with the third approach, experts were asked to propose a weight (percentage) for each of the FIETS dimensions. The analysis of proposed scoring for FIETS dimensions is presented in Table 3.

Table 3. Scoring FIETS dimensions.

Expert Code/Dimensions	IN,01	IN,02	IN, 03	IN,04	IN,05	IN,06	IN,07	IN,08	IN,09	IN0, 10	Avg. (%)
Financial	40	20	20	50	20	25	75	20	15	25	31
Institutional	30	20	20	10	20	15	10	30	20	15	19
Environmental	10	20	20	20	10	20	5	10	15	15	15
Technical	10	20	20	15	30	15	5	30	15	25	19
Social	10	20	20	5	20	25	5	10	30	20	17
	Highest percentages *					Equal percentages **					

Note: * Highest two percentages according to each expert ** Equal percentages according to each expert.

Notably, the financial dimension received the highest weight from five experts, followed by the institutional, technical, social, and environmental dimensions. The financial dimension, in particular, also appears as a primary challenge encountered in achieving sustainability in refugee camps; this is further explained in the following section. The arithmetic mean was applied to analyse the suggested scores, resulting in the following weighted ratings: financial 31%, institutional 19%, technical 19%, social 17%, and environmental 15%.

4.4. Sustainability of WASH: Complexities and Challenges

Experts reported numerous challenges in their efforts to achieve sustainability in WASH programmes presented in Table 4. Initially, they were asked about the necessity of pursuing sustainability in WASH, which was a question that served as an introduction to the key challenges identified across five dimensions: financial, institutional, environmental, technical, social, and political. These challenges align with the FIETS framework, with the addition of specific political aspects.

Specific insights provided by the experts strengthen these findings. Expert IN,03 noted, "Without adequate financial planning, even the best technical solutions will fail in refugee settings". Expert IN,10 emphasised, "A lack of community engagement led to the failure of a pilot sustainable project in Zaatari camp, highlighting the importance of inclusive planning". Furthermore, Expert IN,09 observed, "Disconnects between refugees and host communities exacerbate tensions, making sustainability efforts more challenging".

A recurring theme among nine experts was the issue of financial constraints, with five experts identifying it as the most pressing challenge. One significant financial obstacle in post-emergency contexts, described by Expert (IN,06) and reiterated by Expert (IN,05), is "donor fatigue", the diminishing responsiveness of donors to funding requests from organisations [52]. This highlights the considerable influence of financial issues on the sustainability of WASH in post-emergency situations.

In addition to financial challenges, Expert (IN,03) noted the hesitation among some donors and host countries to fund or support sustainable services in refugee camps, a stance often mandated by host countries as a condition for hosting refugees. This is a considerable constraint, likely tied to broader political dynamics, where host countries do not prefer sustainability in refugee camps to avoid creating tensions with populations in permanent settlements. Furthermore, Expert (IN,10) noted how lack of community engagement contributed to the failure of a sustainable pilot project implemented in the Zaatari Refugee Camp several years ago. Similarly, Expert (IN,09) emphasised the disconnect between refugees and the host community as another significant challenge. These challenges are presented in Figure 2 for further reference and analysis (noting that the size of the bubbles has no significance). The figure emphasises the general financial measures (right-hand side) and financial measures-considerations in the context of post-emergency contexts. This is to prompt the attention of stakeholders on the criticality of financial decisions on the overall sustainability of WASH services in the context of post-emergency contexts.

Table 4. Principal challenges in the sustainability of WASH.

Main Challenges					
Financial	**Institutional**	**Environmental**	**Technical**	**Social**	**Political**
Expensive technical solutions (e.g., desalination)	Disparities services between refugees and host communities	Alternative water resources	Lack of technical managerial expertise	Social discontent between host communities and refugees	Government refuses sustainable solutions
Donors refuse to fund sustainable solutions	Lack of regulations and mechanisms for communities	Water scarcity	No preventive maintenance	Variation in needs (e.g., religious practices)	Lack of clarity on the future of the camp
Operation expenditures	Lack of quick tools (e.g., cost-benefit analysis)		Technical innovations	Equitable distribution	Issues with transboundary resources
Donors fatigue	Poor coordination and communication			Sense of ownership	Lack of host countries involvement
Short-term funding	Unpredictability and unknowns				
	Conventional funding model				
	Identifying priorities				

Note: Background shading has been incorporated to enhance visual clarity and improve interpretability of the data presented.

4.5. Financial Viability of WASH: A Bottleneck

During initial emergency response phases, services are provided free of charge to refugees [31]. In light of this, experts were consulted to propose interventions that could enhance the financial sustainability of WASH services in this context. Expert (IN,01) emphasised that "you cannot charge refugees for water because they are refugees, they don't have an income; they receive subsidies and allowances barely sufficient to cover basic needs". This underscores the difficulty in cost recovery and the reliance on external funding.

Specific interventions proposed by experts highlight practical approaches. Expert IN,02 recommended, "Integrating refugee camps into host-community infrastructure can reduce costs and ensure long-term viability". Expert IN,05 suggested, "Selling treated sludge for compost and reusing rainwater are viable strategies to generate additional income and reduce operational expenses".

The suggested financial actions included ensuring continuous fundraising efforts, applying subsidies, and introducing premium charges for usage that exceeds basic needs, among other proposed strategies (see Figure 2). A few engineering interventions were also proposed to reduce service costs, such as using solar systems for power generation instead of relying on more costly fossil fuels and implementing water usage limits per capita. Additionally, generating income through selling treated water and sludge (e.g., for composting) and reusing rainwater were proposed as strategies to increase revenue and reduce operational costs.

Furthermore, three experts (IN,02; IN,08; IN,09) recommended integrating refugee camps into the host community's infrastructure network. The long-term return on investment could be ensured by utilising humanitarian aid to upgrade these networks, benefiting refugees and host communities.

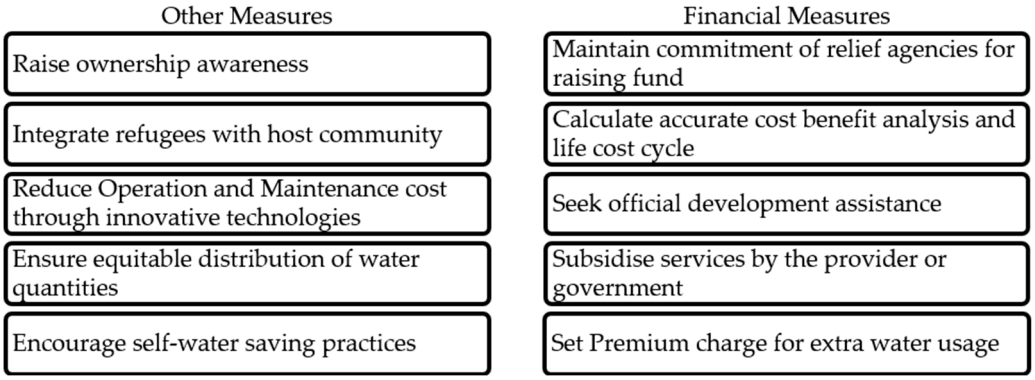

Figure 2. Actions for financial sustainability of WASH.

5. Discussion

Achieving sustainability in post-emergency contexts is complex and often neglected over time, despite being central to fulfilling human rights principles and socio-economic development, which align with the overarching objectives of the SDGs. To provide a comprehensive conceptual framework to assess the sustainability of WASH in post-emergency contexts, FIETS dimensions were chosen due to their positive evaluation in previous studies, such as community-based adaptation in Ethiopia [24] and water investments in West Africa [14]. However, the relative importance of each dimension varies in the literature and is reflected in scoring each dimension [12,14,24,25]. For this research, WASH experts were consulted to rate dimensions of sustainability for post-emergency to ensure that scoring the dimension within the FEITS framework is appropriate for achieving sustainability within the post-emergency context. According to WASH experts, the financial dimension was rated as the most important, followed by institutional, technical, social, and environmental

dimensions. This outcome is expected, given that financial constraints are frequently cited as one of the significant barriers to sustainability in WASH services in refugee camps, including the availability of aid funding [29,30]. The financial dimension presents significant obstacles to supporting other dimensions, thereby influencing the overall sustainability of WASH services. Although precise scores for each dimension were not fully defined in this research, considering the small sample deployed to rate the dimensions, future studies could address this gap. Despite the emphasis on the financial dimension, none of the dimensions should be ignored, as each contributes to sustainability [27].

After identifying the sustainability dimensions for the conceptual framework, 30 sustainability metrics were developed by analysing and categorising 92 sustainability indicators from various WASH sustainability studies and reports [12,13,18,19,21,23,25,50] in a systematic approach, as explained in Section 4. The validation of these 30 metrics and their relevance to post-emergency contexts relied on the input of 10 experts. Twenty-four of the metrics were deemed "very important" by five or more experts for post-emergency WASH sustainability. Six metrics—capital cost recovery, chemical residuals, energy use, age of pipe infrastructure, land use, and climate change adaptation—were considered less relevant for these specific contexts. Future studies may focus on these areas after addressing the 24 primary metrics.

It is important to highlight that among the 92 SIs, none were explicitly linked to the well-being of beneficiaries, despite the importance of this factor in refugee contexts [29]. This gap contrasts with Ref. [49], who prioritised well-being in measuring urban sustainability and liveability. In refugee camps, communities are 'the most vulnerable in society, with no funds, traumatised, people with disability, major chronic health issues, post-traumatic stress are major social and mental illnesses' (Expert IN,09). As previously discussed, the well-being and health of refugees are critical drivers of sustainability and significantly enhance the dimension of social sustainability. It is, therefore, recommended that practitioners, researchers, and policymakers adopting or applying this conceptual framework incorporate these factors as indicators within the social dimension.

Achieving WASH sustainability presents several challenges, with finance identified as one of the most prominent. However, experts have also highlighted several factors, classified into financial, institutional, environmental, technical, social, and political dimensions, as illustrated in Table 4. Political factors emerged as significant barriers, with Experts (IN,03) and (IN,08) noting the reluctance of host countries to implement sustainable WASH services to avoid 'implicit recognition' for refugees and refugee camps as permanent settlements. Additionally, Experts (IN,04) and (IN,09) highlighted a lack of clear plans for refugee camps from the host country, which in some cases is linked to the shortage of funds needed to operate those camps. Financial challenges were also underscored, including donor reluctance to fund sustainable solutions (Expert IN,03) and "donor fatigue" during the post-emergency phase following generous funding during the emergency phase (Expert IN,06).

Institutionally, the conventional humanitarian funding and implementation model, which is based on assessing camp needs and implementing projects without evaluating the implementing organisation's ongoing role, was identified as problematic (Expert IN,02), meaning that some organisations are concerned more with maintaining their operations rather than the necessity of deploying sustainable solutions that would last without their presence. Furthermore, institutional challenges relate to camp management in addressing the need for sustainable planning to ensure continuity of services post-funding (Expert IN,10). Environmentally, groundwater depletion (Expert IN,01), water scarcity (Expert IN,06), and the availability of alternative water sources (Expert IN,01) are all key issues that must be addressed to ensure the sustainability of water supply. Technical challenges

included the lack of innovative solutions and preventive maintenance (Experts IN,05 and IN,06).

Social-sustainability-related challenges and factors varied, including health, safety, community ownership and integration within the host community. The underestimation of communities' vulnerabilities in refugee camps and the positive impact of sustainable services on refugee's health by donors and organisations is a challenge to achieving sustainability (Experts IN,06 and IN,09). Expert (IN,09) highlighted that constructing sustainable piped networks is a challenge considering the level of safety required inside camps. Experts (IN,06, IN,09 and IN,10) emphasised the necessity of community ownership to avoid facility sabotage and failure of services over time. An interesting driver to the sustainability of services in refugee camps raised by Expert (IN,09) was the proposed integration between refugee camps and host communities that can have beneficial social sustainability implications for both communities. A promising model for addressing these social issues can be found in Kenya's Kalobeyei settlement, designed to integrate refugees with host communities, fostering socio-economic integration and sustainability [15]. This model could serve as a blueprint for future refugee camps.

In comparison to existing sustainability tools, this research highlights the significance of focusing on FIETS dimensions that influence the overall sustainability of WASH, especially in complex scenarios such as post-emergency camps. While the FIETS framework incorporates dimensions from other sustainability tools, this study identified that the financial dimension is the most impactful, which can influence achieving other dimensions such as institutional, environmental, technical and social. It is important to recognise that the FIETS presented in this study would support decision-making in the short and long terms as WASH services in post-emergency camps require continual monitoring and assessment in terms of their sustainability. Besides the value of mapping FIETS into WASH systems within post-emergency contexts, qualitatively, the study has identified an emerging, perhaps at a macro level, dimension, which is the political dimension. Whilst the presence of such a dimension is expected in such a context, it has a significant role in terms of the challenges it presents to achieve sustainable WASH systems in refugee camps. Political factors such as reluctance to integrate refugee camps into host communities or to invest in long-term solutions significantly hinder sustainability. To address these issues, it is essential to expand the theoretical understanding of the impact of the political dimension within the FIETS framework. A recent study by Ref. [53] highlighted that political aspects in refugee camps present a prevailing challenge because they can impact accessibility, the inclusion of humanitarian organisations, and the supply of systems that support the infrastructure for sustainability in such contexts. Based on the challenges identified in Table 4, it is important to understand the synergy between different FIETS dimensions.

The DRT-FIETS framework (Figure 3) offers a significant advancement over the existing FIETS framework by introducing "Donors", "Regulatory", and "Technology" as key streams that address critical gaps in the sustainability of WASH systems in refugee camps. By explicitly integrating these streams, the framework enhances the ability to address interconnected challenges and provides a more informed, holistic approach to decision-making and implementation.

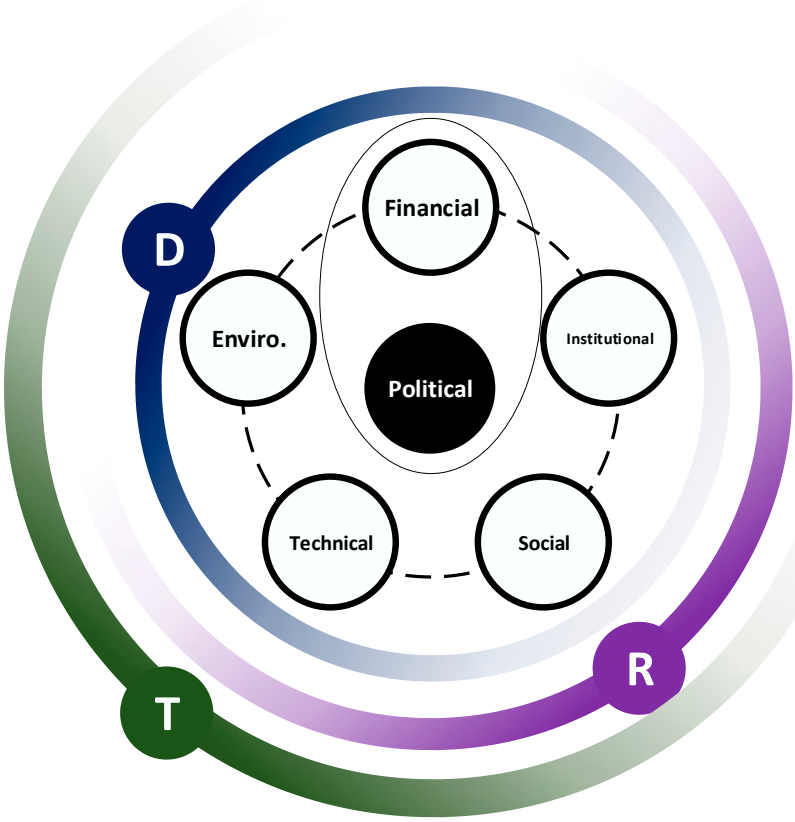

Figure 3. DRT-FIETS Conceptual Framework. Note: Background shading has been incorporated to enhance visual clarity and improve interpretability of the data presented.

The Donors stream addresses the multifaceted role of financial, environmental, and technical contributions in sustaining WASH systems. Donors play a pivotal role in mitigating financial constraints [16,29,30] that dominate post-emergency contexts. The framework highlights the importance of donor engagement, funding mechanisms, and accountability to overcome challenges such as donor fatigue and reluctance to invest in long-term solutions. Unlike the financial stream in FIETS, which primarily focuses on monetary aspects, the DRT-FIETS framework delves deeper into the dynamics of donor relationships, emphasising their influence on technological innovations and environmentally sustainable practices. For instance, donor-driven initiatives can fund advanced water systems and promote resource efficiency, ensuring the resilience of WASH services in resource-scarce environments such as refugee camps.

The Regulatory stream integrates social, institutional, and technical needs, focusing on the governance and legal frameworks that either enable or hinder WASH sustainability. Regulatory factors, including host-country policies and institutional accountability, often determine the feasibility of implementing sustainable systems in refugee camps. By consolidating these elements into a regulatory stream, the framework acknowledges the critical role of governance in ensuring the continuity and integration of refugee camps into host communities. While FIETS incorporates institutional and social streams, it lacks a comprehensive focus on regulatory aspects, such as host-country reluctance to invest in permanent infrastructure. The DRT-FIETS framework addresses these gaps, emphasising the need for clear, sustainable planning to extend WASH services beyond the post-emergency phase. This regulatory focus aligns with real-world challenges, providing a structured approach to overcoming policy and governance-related barriers. This will also allow an enhanced approach towards community-based approaches, providing further potential for long-term sustainability within refugee camps.

The Technology stream highlights the transformative potential of technological advancements in connecting technical, environmental, and social progress. Technology serves as a critical enabler of innovation, offering solutions to technical challenges such as preventive maintenance, monitoring, and resource optimisation. By explicitly integrating technology into the framework, the DRT-FIETS model underscores its role in fostering environmental sustainability through energy-efficient systems and enhancing social outcomes by improving health and accessibility. Unlike FIETS, which treats the technical stream as broad and somewhat static, the DRT-FIETS framework emphasises technology's evolving nature and its ability to address interconnected challenges. Scalable innovations, such as smart water systems [54], digital monitoring tools, and renewable energy solutions, are vital for addressing unique challenges in refugee camps. Furthermore, this stream aligns with global trends in digital transformation, such as Industry 4.0 and digital twins, ensuring the framework's adaptability to future technological advancements.

The DRT-FIETS framework provides a more informed approach to addressing the sustainability of WASH systems in refugee camps. By interlinking financial, institutional, technical, environmental, and social factors within a structured lens, the framework offers clarity on the roles and interactions of key actors, such as donors, regulatory bodies, and technology providers. This holistic integration not only facilitates a comprehensive understanding of sustainability challenges but also enhances the ability to prioritise interventions effectively. Furthermore, the framework explicitly addresses real-world barriers, such as political reluctance, donor fatigue, and inadequate regulatory frameworks, ensuring that practical challenges are at the forefront of decision-making processes.

Incorporating technology into the framework ensures its scalability and adaptability to diverse contexts and emerging innovations. For example, community-based water monitoring systems can foster sustainability while enhancing community ownership, a critical factor in maintaining the long-term functionality of WASH systems. The DRT-FIETS framework also supports enhanced decision-making by offering a roadmap for multi-stakeholder collaboration, providing a clear understanding of how various streams interact and influence sustainability. By expanding on the existing FIETS framework, the DRT-FIETS model creates opportunities to address complex challenges with greater precision and efficacy, making it a robust tool for guiding sustainable development in post-emergency contexts.

6. Conclusions

In conclusion, this study addresses a critical gap in the literature by proposing a modified framework to assess the sustainability of WASH services in refugee camps. The research highlights the significance of adopting FIETS dimensions to unpack the complex, multidimensional nature of sustainability in post-emergency contexts. The findings emphasise that financial sustainability is the most crucial factor, followed by institutional, technical, social, and environmental considerations. Key challenges, such as limited funding, political obstacles, and resource constraints, underscore the need for collaborative efforts among stakeholders to ensure the long-term viability of WASH services in these vulnerable settings.

To support practitioners and policymakers in implementing the proposed framework, the following recommendations are offered:

- Adopt a phased approach: Begin by prioritising the financial dimension, ensuring stable funding mechanisms through diversified donor models, integration with host community infrastructures, and income-generating activities such as selling treated sludge or compost.

- Develop capacity-building programs: Train camp staff and community members in sustainable WASH practices, preventive maintenance, and the use of innovative technologies tailored to refugee camp settings.
- Enhance stakeholder collaboration: Establish partnerships between humanitarian organisations, local governments, and host communities to co-design and implement sustainable WASH solutions.
- Implement monitoring and evaluation systems: Use the metrics and thresholds outlined in this study to continuously assess WASH service performance and make data-driven adjustments.

This DRT-FIETS framework offers a practical tool for policymakers and practitioners to evaluate and enhance WASH services, contributing to the broader goals of sustainable development and water resource management in refugee camps. More importantly, it also sets the priorities to overcome issues in a more structured and constructive approach. Future work should focus on applying the developed framework and also look into how integrating WASH services in camps with surrounding cities would enhance the overall sustainability of services.

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