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A framework to support localized solid waste management decision making: Evidence from Qatar

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ABSTRACT

Solid waste management is a pressing global issue, aligning with Sustainable Development Goals 11 and 12. Despite increasing awareness, the annual rise in waste generation is expected to persist for decades. Efficient waste management is crucial for channeling valuable resources into circular economy flows while safeguarding health and the environment. While best practices are informative, localized actions tailored to specific contexts are essential. This study proposes a thematic framework, grounded in techno-policy, to prioritize actions for achieving sustainable solid waste management (SSWM) in Qatar, with potential applicability to other countries. The prioritized recommendations include enhancing research and policy coordination, harnessing value from waste, fostering interdisciplinary collaboration, and promoting awareness campaigns. The study underscores the significance of private sector training, plastic recycling, and addressing the impact of mega-events on waste management. It identifies key stakeholders, such as researchers, businesses, government, and the community, emphasizing their roles in implementing effective waste management strategies. Challenges, however, arise from the absence of comprehensive and up-to-date open data, hindering a full understanding of recent developments and identification of priority areas for future research. In summary, this study introduces a novel techno-policy-driven framework for prioritizing SSWM actions, emphasizing the need for targeted efforts in diverse contexts to address the escalating global waste challenge.

1. Introduction

The overwhelming majority of purchased items are thrown out in just months, resulting in billions of tons of waste annually (International Institute for Sustainable Development, 2018). This is not only a concern regarding consumer habits and resource management; improperly managed waste has economic consequences and poses significant health and environmental risks. Waste can contaminate soil, water, and air, harm wildlife and marine life, and contribute to climate change by releasing greenhouse gases (Ayilara et al., 2020). Although recognized as a global issue of concern for decades, the amount of waste being generated annually is increasing at an alarming rate. Therefore, finding efficient and effective ways to manage and dispose of it is crucial. According to the World Bank, it is projected that urban waste worldwide will experience a substantial growth of 70% compared to 2016 levels by the year 2050 (Kaza et al., 2018). This increase will result in a staggering amount of waste, reaching 3.4 billion tons. The Sustainable Development Goals (SDGs) (11 and 12) have set targets specifically around waste management, which includes reducing the amount of

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Abbreviations

BRIC	Brazil, Russia, India, and China
ESG	Environmental, Social, and Governance
GA	Government Agencies
GCC	Gulf Cooperation Council
ICT	Information and Communication Technology
IPCC	Intergovernmental Panel on Climate Change
MENA	Middle East and North Africa
MME	Ministry of Municipality
MOECC	Ministry of Environment and Climate Change
MOEHE	Ministry of Education and Higher Education
MOPH	Ministry of Public Health
MSDF	Ministry of Social Development & Family
MSW	Municipal Solid Waste
NDCs	nationally determined contributions
PPP	public-private partnerships
QNDS	Qatar National Development Strategy
QNV	Qatar National Vision
RS	Researchers and Scientists
SDGs	Sustainable Development Goals
SLR	systematic literature review
SMEs	small and medium-sized enterprises
SPs	service providers
SSWM	Sustainable Solid Waste Management
SWM	Solid Waste Management

waste generated, increasing recycling and composting, and safely disposing of the waste that cannot be eliminated. In addition to harm prevention, implementing circular resource flows can lead to positive outcomes for society and the environment (Do et al., 2021). Also, the circular economy business model exhibits robust correlations with several SDGs, underscoring its potential impact on diverse societal and environmental aspects. Particularly noteworthy are the strong associations between the circular economy model and the objectives of SDG4 (Quality education), SDG5 (Gender equality), SDG7 (Affordable and Clean Energy), SDG8 (Decent working and economic growth), SDG9 (Industry, innovation, and infrastructure), SDG11 (Sustainable cities and communities), and SDG12 (Responsible consumption and production) (Puntillo, 2023). To have efficient and effective solid waste management (SWM) systems, however, the approaches must be tailored to local needs and be appropriately designed. While there is international solid research on SWM, it is important to research waste management in each context and identify feasible and impactful ways to improve it.

Due to high waste production rates, a lack of disposal options, and inadequate waste management strategies, the majority of the countries in the Middle East are grappling with severe environmental issues emanating from inappropriate SWM. It is not only that their systems are inadequate, however, as nations within the Middle East region (e.g., Saudi Arabia, Kuwait, the United Arab Emirates, Qatar, and Bahrain) are among the top global per capita garbage producers, with the region yearly producing over 150 million tons of solid waste (Zafar, 2018). One-third of global waste is generated in Asia, where China and India have between 0.44 and 4.3 kg and 0.50 and 0.9 kg per person per day, respectively (Khan et al., 2022b). On the other hand, the Gulf Cooperation Council (GCC) nations—namely, Saudi Arabia, Bahrain, the United Arab Emirates, Qatar, Oman, and Kuwait—generate more waste (>1.5 kg/capita/day) than the global average of 1.2 kg per person per day (Khan et al., 2022b). The high standard of living in these countries, coupled with growing populations, is expected to increase total waste production. Also, the recycling sector in the GCC region is underdeveloped, with only a small percentage of waste being recycled (Mariyam et al., 2022). Developing a sustainable framework for waste management in the GCC countries is essential to address these challenges. The development of waste management in the region, including private sector actors, has been hampered by a lack of appropriate institutional and regulatory frameworks, combined with rapid economic growth that has caused the waste management infrastructure to be unable to keep up with that pace. Even though there have recently been improvements to infrastructure and management systems in the region, more work is still needed (Zafar, 2018).

SWM issues, despite their significance and potential harms, lack extensive research and sufficient data for evidence-based decision-making (Mariyam et al., 2022). It is crucial to leverage existing evidence to enhance current waste management systems and identify research priorities for the future. This paper aims to utilize the results of a systematic literature review (SLR) of waste management issues in one GCC country, the State of Qatar (Mariyam et al., 2022), to provide recommendations for system strengthening. This country case study is significant as it offers insight into the unique context of a rapidly developing economy, the findings and recommendations of which will be insightful for other countries. More importantly, the thematic framework provides a model for prioritizing actions for the greatest impact.

This paper provides an overview of the current state of waste management in Qatar. It offers recommendations for improvement by applying a thematic framework that assists in prioritization. This study focuses on three main objectives: (i) guide evidence-based

decision-making and support the strengthening of existing waste management systems by utilizing recommendations from an SLR; (ii) develop sustainable solid waste management (SSWM) framework to reduce the negative impacts of waste on health and the environment, improving economic efficiency, and promoting the shift towards circular resource flows in Qatar; (iii) discuss the significant stakeholders and their roles in Qatar for improved SSWM.

Developing a framework for SSWM is important because it addresses the pressing issues caused by improper waste management. The negative impacts (such as climate change) can be reduced by improving waste management, and positive outcomes (such as the circular economy) can be achieved through shifts toward circular resource flows. Additionally, developing a framework allows for the utilization of existing evidence to enhance current systems and inform future research requirements. Further, such a framework is critical in rapidly developing economies like the GCC countries, where waste management systems may be unable to keep pace with the rising volume of waste and population growth. In this way, an SSWM framework can help these countries mitigate the negative effects of waste and contribute to sustainable development in a way that prioritizes activities and investments with the most significant impact.

Given the specificity of each country and its waste management situation, this paper first provides an outline of the country and the context of the study. This is followed by the methodology section, which is divided into three subsections, namely: (1) a review of existing published SWM frameworks and a discussion of their key features and approaches; (2) an explanation of the methodology employed for the SLR conducted in this study, including the search strategy, inclusion/exclusion criteria, and data extraction process; and, (3) an outline of the data analysis methodology used to organize, categorize, and summarize the collected data. The findings of the SLR and the data analysis carried out during the study are presented in the results and discussion section. Following a discussion and analysis of the data pertaining to the SWM frameworks and literature review, it gives a summary of the key themes, patterns, and insights extracted from the studied literature. This study introduces a framework for SSWM, and its practical application—including its essential elements and procedures—is covered.

It also covers the restrictions and difficulties connected with putting the SSWM paradigm into practice, taking into account things like resource limitations, regulatory obstacles, and social acceptance. The article highlights the contributions and importance of the research in the conclusion section, which summarizes the key discoveries and learnings from the study. Additionally, it recommends possible directions for further study and advancements in SWM frameworks.

This study introduces a noteworthy contribution to waste management through its innovative approach in developing an SSWM framework. The novelty of this research lies in its thorough exploration of the unique challenges faced by rapidly developing economies, particularly within the GCC countries. By specifically focusing on the State of Qatar, the study addresses a critical gap in the literature, offering contextually relevant insights applicable to countries experiencing similar challenges in waste management. This research pioneers a holistic model that goes beyond conventional practices by examining the interplay of technological advancements and policy interventions in waste management. The SSWM framework presented in this study is not merely a theoretical construct. Still, it offers a pragmatic guide for decision-makers and stakeholders in waste management, emphasizing the need for tailored strategies in diverse contexts. This novel approach positions the research as a valuable resource for academics, policymakers, and practitioners seeking effective solutions to the escalating challenges of waste management in rapidly developing economies. The study's contribution is not confined to exploring problems; rather, it sets a precedent for innovative, context-specific solutions that can pave the way for sustainable development in global waste management practices.

2. Country and study context

Qatar is a small, oil-rich country located in the Middle East on the northeastern coast of the Arabian Peninsula. Saudi Arabia borders it to the south and the Arabian Gulf to the east. Qatar has population is around 2.7 million; most of its residents are expatriates ([Population and total-Qatar, 2022](#)). The country has a high standard of living and is known for its modern infrastructure, advanced healthcare system, and high levels of education. Qatar falls under the highest tier possible ("Very High") for the Human Development Index (HDI), with a score of 0.855 in 2021 ("[Human Development Index \(HDI\) by Country \(2023\)](#)," 2021). Qatar is also known for its wealth; with a GDP per capita of over \$66,838 reported in 2021, it has one of the highest in the world ([The World Bank, 2021](#)). Through strategic planning and partnerships with customers, technology suppliers, and investors, Qatar successfully transformed its economy into one driven by natural gas, resulting in a significant increase in GDP ([Hjeij et al., 2022](#)).

Like other GCC countries, Qatar has formulated a blueprint, the Qatar National Vision (QNV) 2030, to achieve its long-term goals and establish a structure for executing its national strategies. HH Shaikh Tamim bin Hamad Al-Thani, the heir apparent, unveiled the plan in October 2008 after receiving approval from Amiri Decision 44 ([General Secretariat for Development Planning, 2008](#)). The State of Qatar seeks to enable effective development by balancing the needs for environmental preservation, social development, and economic progress. Qatar also plans to take the initiative in the region to assess the effects of climate change and lessen its detrimental effects. To comply with their nationally determined contributions (NDCs) for the Paris Agreement commitments and COP26 pledges, Qatar has set a goal of reducing GHG emissions by 25% by 2030 ([Dargin, 2021](#)). However, despite having the world's highest per capita carbon emissions (35.77 tons per person), Qatar has not declared any net-zero targets or specific investment goals for renewable energy. Also, although significant new research on sustainability in Qatar has been published ([Cochrane and Al-Hababi, 2023a](#)), SSWM policy has received relatively limited academic attention.

The vision also intends to establish a thorough, sustainable urban development plan considering population distribution and urban growth. The government wants to raise awareness within the population so everyone shares the value and importance of protecting Qatar's natural resources and neighbors. To do this, it aims to set up efficient and cutting-edge environmental institutions that promote eco-friendly technologies, carry out awareness campaigns, and undertake environmental research. The vision also outlines the role of

the private sector and the requirement for world-class infrastructure and ongoing improvements in government institutions' effectiveness, accountability, and transparency. In line with this plan, several research projects and strategies have been launched to advance the protection of the environment and the country's human, social, and economic components.

A previous author's publication conducted an SLR on available evidence regarding waste management in Qatar (Mariyam et al., 2022). That publication discussed the main waste management issues in Qatar, including the increasing waste generation, lack of systems approaches for waste management, low rates of recycling, and challenges in construction waste management. Those issues will not be extensively discussed here; we refer readers to that paper for those details (Mariyam et al., 2022). For brief context, over half of the municipal solid waste produced in the country is sent to landfills (Abbasi, 2018). Additionally, the country's renewable energy capacity is relatively low at only 0.4%, mainly consisting of biomass and waste generated through incineration, which accounts for 38% of Qatar's renewable energy capability. However, recent articles report Qatar is implementing a plan for transition to clean energy, which involves increasing solar capacity to over 5 GW; as part of this plan, the 800 MW Al Kharsaah Solar PV IPP Project will become the world's largest solar power plant and producing 10% of Qatar's peak electricity demand ("Al Kharsaah, a pioneering solar power plant in Qatar," 2023; Ataulloh, 2023). Within the next two years, Qatar plans to build two more solar power plants with a combined capacity of 880 MW. Nevertheless, there is promise in managing waste for electricity markets (as well as other value-added products), with some electricity already generated from municipal solid waste due to incineration.

Most of the available research on waste management focusing on Qatar discusses the increasing interest and research in creating economic value from waste through energy, agriculture, and water treatment applications. However, most studies focus on using single types of waste on a laboratory scale. Thermal treatment methods such as pyrolysis and gasification offer environmentally sustainable alternatives that have the potential to transform waste into value-added products, including fuel generation, power generation, and soil bioremediation (Marsh and Steer, 2021). Single wastes were found to create positive synergies in the transition to energy-efficient buildings using date pits (Marri et al., 2021), for agricultural applications such as organic fertilizers using wastewater sludge (Majeed et al., 2021), and for water treatment applications, such as using ash from incinerated municipal solid wastes (Al-Ghouti et al., 2020a). Given that wastes are largely not segregated, there is a need for a broader systems transformation to fully realize the potential of waste-to-value added strategies in Qatar.

Qatar's specific challenges, such as construction projects and the related generation and management of waste, are distinct and specific to the country. Qatar went through significant urban and infrastructure development, with the capital city Doha transforming from a small town to a vibrant center with an attractive waterfront area and distinctive skyline, in addition to infrastructure built for the FIFA World Cup Qatar 2022™. The construction industry is thriving due to the (ongoing) expansion and enhancement of infrastructure, transportation networks, and the urban landscape, ensuring continued growth in the years to come. Waste management has become increasingly a priority (Mariyam et al., 2022). Although an increasing amount of research is available, no studies (to our knowledge), review all the recommendations made and prioritize actions and investment based on impact. A recent review on utilizing

Table 1
Summary of published articles on SSWM.

Country/Region	Objectives	Methodology	Findings	Reference
Europe	Analyze construction and demolition waste management in Europe using the waste hierarchy framework, with a focus on waste concrete.	Literature reviews, field surveys, face-to-face interviews	The waste hierarchy now prioritizes waste prevention and resource efficiency. Innovative treatment methods for CDW, particularly waste concrete, were investigated.	Zhang et al. (2022)
Brazil, Russia, India, and China (BRIC)	Develop a thematic framework for low-income countries' municipal solid waste management	Qualitative research method involving systematic review of printed and electronic material	Identified themes: indiscriminate MSW disposal, education campaign, waste diversion, commitment, statistical data, long-term strategies, licensing, and strategic framework suitable for low-income countries	Zorpas (2020)
Municipalities in developing countries	Propose a framework for sustainable and integrated municipal solid waste management in developing countries	Systematic literature review	Identified nine barriers to sustainable waste management in developing countries. Proposed a framework considering social, economic, and environmental dimensions of waste management	Batista et al. (2021)
Developed, developing and underdeveloped countries	Identify the state of the art and conduct a SWOT analysis of organic waste management through circular economy principles	Systematic literature review	Identified weaknesses such as logistic cost, seasonality, lack of homogenization, and lack of economic competitiveness. Emphasized the need for public policies, standards, and stakeholder involvement. Acknowledged limitations of the study.	Alberto et al. (2019)
N/A	Investigate prior research on food waste in the profit sector of hotels, restaurants, cafes, etc.)	Systematic literature review	Identified research themes, research gaps, and proposed actionable recommendations and a framework for future investigations into the multidimensional nature of food waste	Dhir et al. (2020)
Cairo	Gather data on waste management practices in Cairo	In-depth analysis of existing waste management models and approaches	Identified challenges and developed a framework for waste management in developing urban areas, considering social and environmental factors.	Elsaid and Aghezzaf (2015)

oil and gas wastes discuss the importance of engaging in discussions with stakeholders to assess the environmental and economic viability of implementing large-scale resource recovery (Shahbaz et al., 2023).

This study addresses the pressing issue of waste management in Qatar and provides such a prioritization. Doing so requires a comprehensive framework to enhance the circular economy and achieve sustainable development while preserving the environment. The current linear economy model of (mostly) 'take-make-dispose' has significantly increased waste generation, with little emphasis on resource efficiency and recycling. However, a new approach to waste management can transform waste into a valuable resource, reduce reliance on virgin materials, and provide economic opportunities by creating new businesses and jobs while reducing the environmental impact of waste disposal. Additionally, a robust waste management framework can ensure that all sectors safely dispose of waste without polluting the environment or affecting human health. A lot is required for this to happen, decision makers and various stakeholders need support in prioritizing activities and investments. A comprehensive waste management framework that prioritizes the circular economy, sustainable development, and environmental protection is crucial for Qatar's future prosperity and well-being, to which this paper contributes.

3. Methodology

3.1. Published SWM frameworks

Developing a sustainable waste management system is crucial to meet the specific needs of a given context. While directly importing assessments or practices from other countries may not be suitable, examining similar frameworks can be beneficial. This allows us to discover best practices, strategies, and technologies to inspire and guide our waste management initiatives. Understanding the importance of waste collection, segregation, and economic models in these countries helps us evaluate our current practices and identify areas for improvement. By combining insights from existing frameworks with a deep understanding of our local environment, we can develop customized waste management approaches that are environmentally responsible, economically viable, and socially equitable. Therefore, this section and Table 1 intend to discuss some of the published SWM frameworks in the literature.

The table presents a collection of studies conducted in different regions, including Europe, Brazil, Russia, India, China, developing countries, and specific cities such as Cairo. These studies employ various methodologies, such as literature reviews, field surveys, interviews, and systematic reviews. The findings shed light on several crucial aspects of waste management, such as the waste hierarchy, innovative treatment methods, thematic frameworks, contextual barriers, strengths, weaknesses, and challenges. Moreover, the studies emphasize the significance of considering waste management's social, economic, and environmental dimensions. They focus on specific waste management issues, including construction and demolition waste, municipal solid waste, organic waste, and food waste in the profit sector. The studies propose recommendations, such as the need for public policies, standards, stakeholder involvement, education campaigns, waste diversion, and long-term strategies. While some efforts to support localized decision making for sustainability have been conducted in Qatar (Cochrane and Al-Hababi, 2023b), we are not aware of any studies of this nature for SSWM. Overall, the contents of the table provide valuable insights into the importance of adopting a holistic thematic framework for sustainable waste management in Qatar.

Some studies focus on developing research agendas by analyzing literature. A more relevant article published by Batista et al. on integrated SSWM analyzed 75 articles and identified eight barriers and eleven critical success factors. They then categorized them into five pillars: public policies, disposal techniques, legal aspects, public-private partnerships (PPP), and energy recovery (Batista et al., 2021). However, the limitation of the study in choosing narrow keywords and the subjectivity of the researchers was discussed. Dhir et al. discussed a research agenda for managing food waste in the hospitality and food services sectors (Dhir et al., 2020). They used an SLR and framework development approach, which allowed them to identify five main research gaps related to data and analysis. They also suggested potential research areas and created a framework for addressing food waste and loss. However, it did not develop a framework that can aid in a holistic approach to addressing SWM. Although SWM frameworks have been conducted in the west, comparatively few studies have been undertaken in the Middle East and North Africa (MENA) region. One study offers insights into creating a more efficient and integrated sustainable waste management system suitable for developing economies by studying Cairo (Elsaid and Aghezzaf, 2015). The paper discussed the challenges of updated waste data in Egypt and heavily relied on estimate numbers and the requirement to design a transportation model for an effective SWM. Although many reviews have been recently published on SWM (Hemidat et al., 2022; Hussein et al., 2022; Mariyam et al., 2022), to the best of the authors' knowledge, this is the first evidence-based SSWM framework developed in the region. Developing a tailored framework for Qatar allows for the alignment of waste management strategies with the specific needs and circumstances of the country. By conducting research and analysis specifically focused on Qatar, it is possible to identify the unique challenges, opportunities, and requirements for implementing an SSWM well-suited to the country's needs. Considering the QNV 2030 and the associated increase in publications for waste management, the methodology for developing the SSWM focuses on utilizing the knowledge received from a SLR, as outlined in forthcoming sections. While this approach is tailored to a specific context, the methodology could be applied in other contexts.

3.2. SLR of this study

The purpose of the previously published systematic review was to examine the current state of waste management research in Qatar by identifying, researching, and analyzing relevant studies published on the topic (Mariyam et al., 2022). The SLR in this paper aimed to identify and analyze research on waste management in Qatar by conducting an updated comprehensive search using the academic databases ProQuest and SCOPUS, following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses for Protocols

(2015) guidelines. Both databases were intended to broaden the study's scope and complement each other, as SCOPUS is known for its comprehensive coverage and data quality, while ProQuest offers unique search features.

On October 30, 2022, an updated systematic review search was conducted using the keywords "Qatar," "waste," and "management." The inclusion criteria for the search spanned from 2011 to 2023, aiming to capture the most recent evidence and recommendations in the field (and conversely, avoid the inclusion of out-of-date recommendations from decades past). Using the specified keywords and temporal parameters, 3347 articles in RIS format were downloaded and uploaded to Rayyan, a web tool for managing articles during systematic reviews. This tool facilitated efficient screening of articles as multiple authors could simultaneously review titles and abstracts on a single platform. Fig. 1 provides an overview of this study's systematic search and review processes. In total, 95 articles were reviewed as part of this research.

The previous study identified ten major themes in existing literature based on the subject and objectives of the studies, which included supply chain, economics, plastic, sports, construction, sustainability and environment, food, management, waste to value, and religion (elaborated further in Table S1). The themes were then categorized based on the authors' understanding of importance from 1 to 5, with 5 representing the most urgent priority, 1 (Mariyam et al., 2022). Category 5 represented the need for a comprehensive management structure for waste, while category 4 focused on utilizing and recycling waste materials. Category 3 addressed sustainability, economics, and supply chain management, category 2 highlighted utilizing sustainability initiatives during mega events and waste plastics management, and category 1 suggested the incorporation of religion in waste management. The methodology utilized in this study captured the recurring themes in the updated 95 articles. It then creates a database of all the policy recommendations made in the updated literature (95 articles) to develop an evidence-based thematic framework to address SSWM in Qatar. This study bases the priority actions on the frequency of recommendations in reviewed literature rather than the decision from the authors of this study, which makes the framework reliable and evidence-based.

3.3. Data analysis methodology of this study

The data analysis conducted in this study included collating the recommendations or prospects suggested in the 95 reviewed articles. In addition to applying the framework to prioritize those recommendations and prospects, the authors offer a discussion based on the results and the required actions that are presented. One of the methods for understanding the importance of recommendations and prospects is the frequency with which the suggestions are made, which was recorded in a database when the articles were qualitatively analyzed. Since the suggestions involved different actors, the stakeholders responsible for practically implementing the action were also recorded. When this was not explicitly mentioned (i.e., a recommendation was made generically without specifying which actor is responsible for funding and/or implementing it), the authors added a stakeholder analysis process to the thematic framework to identify the most appropriate stakeholder. Finally, to examine how much support is practically possible in the context of Qatar, the suggestions were categorized, by stakeholder, based on three spheres of control: (i) Area of control: if the suggestion has components that the stakeholders have direct control over, (ii) Area of influence: if the stakeholders can exert influence but is not solely

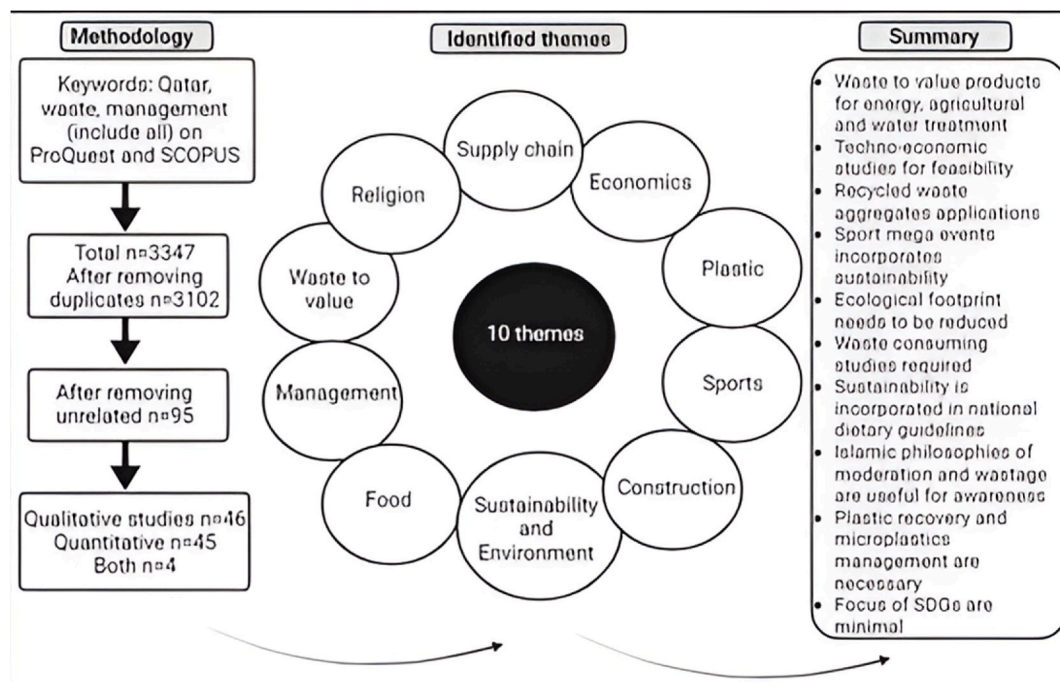


Fig. 1. Systematic review process, identified themes, and a summary of findings.

Table 2
Summary of the data analysis of the SLR.

Category No. from highly recommended to lowly	Required action	Area of consideration/ Frequency/ Stakeholders	Strategy and Enforcement	References
I.	Research-policy coordination	Concern/17/GA + RS + PS	Integrate researchers, businesses, government, and community	(Ben Hassen et al., 2020; "Gulf delegation visits Domestic Solid Waste Management Centre in Mesaieed," 2022, "HIA's new feat in waste management," 2022, "New waste management center to develop circular economy in Qatar," 2022, "Qatar: Ashghal mandates sustainability on sites for MOTC public bus transport program project," 2021, "Qatar's airport to recycle waste for landscaping and provide compost to third parties," 2022, "Qatar makes great strides in waste recycling: Official," 2022, "Qatar University promotes several sustainability initiatives during Qatar Sustainability Week, 2022;" 2022, "QNRF seminar shines light on solutions for sustainable waste management in Qatar," 2022; Hussein et al., 2022; Kuncic, 2018; Lang and Mason, 2018; Mrabet et al., 2017; Poudineh et al., 2021; Reid et al., 2016; Salem et al., 2021; Sharma and Jain, 2020)
II.	Waste to value market	Concern/15/GA + PS	Develop market for circular economy	(Al-Absi et al., 2021; Al-Ghouthi et al., 2020a, 2019; Al-Moftah et al., 2021; Alghazo et al., 2019; Ali et al., 2021; El-Azazy et al., 2021, 2019; El-Shafie et al., 2022; S. Elkhailifa et al., 2019a,b; Hahladakis et al., 2020; Hassan et al., 2016; Hassan et al., 2020; Majeed et al., 2021; Rehrah et al., 2018)
III.	Specific research areas encouragement	Influence/14/GA + RS	Utilize and conduct sustainability related projects	(Aktas et al., 2018; Al-Ghouthi et al., 2020b; Al-Rumaihi et al., 2020; Alagha et al., 2022; Alhazmi et al., 2021; Samar Elkhailifa et al., 2019a,b; Marri et al., 2021; Nair, 2021; Niles et al., 2018; Shah et al., 2014; Shahbaz et al., 2023; Sharif and Irani, 2016; Tokgoz et al., 2016; Zyoud et al., 2015)
IV.	Awareness campaigns on SDGs, Islamic markets, curricula, consumerism	Control/9/GA + RS + PS	Update and integrate waste management system in all sectors	(Abbasi, 2018; Abdelzaher and Abdelzaher, 2017; Al-Thani et al., 2021; Brennan and Browne, 2021; Conrad et al., 2018; El Bilali and Ben Hassen, 2020; Fekih Zguir et al., 2022; Sharif, 2016; Sharif et al., 2019)
V.	Private sector training and ESG driven approach	Influence/8/PS	Update and integrate waste management system in all sectors	(Ahmed et al., 2020; Al-Shboul, 2017; Chen et al., 2018; Fatema et al., 2020; Irani et al., 2018; Khovrak, 2020; Rybkowski et al., 2017; Zhang et al., 2018)
VI.	Plastic recycling and market	Influence/7/GA	Update and integrate waste management system in all sectors	(Al-Maaded et al., 2012; da Costa et al., 2020; Gonçalves, 2019; Hahladakis and Aljabri, 2019; "QC panel holds meet to review MME proposals for regulating, recycling and treating waste," 2020; Sakshi et al., 2021; Srinath et al., 2020)
VII.	Lessons from mega events (FIFA World Cup Qatar, 2022™)	Control/6/GA + RS + PS	Utilize and conduct sustainability related projects	(Al-Hamrani et al., 2021; Cup, 2021; Fermeglia, 2017; Koç, 2019; Preuss, 2013; Taqa et al., 2021)
VIII.	Research & development	Influence/4/RS + PS	Integrate researchers, businesses, government, and community	(Al-Ansari et al., 2016, 2017; Al-Jabri et al., 2021; Ghat et al., 2022)
IX.	Utilizing Indicators for Assessing Waste Impacts and Sustainable Transformation	Control/3/GA	Utilize and conduct sustainability related projects to achieve SDGs	(Chia-Nan et al., 2021; Godwell et al., 2020; Lin et al., 2019)
X.	Transparency in data	Influence/3/GA + RS	Integrate researchers, businesses, government, and community	(Abdelaal et al., 2019; Al-Thani et al., 2022; Alshawaf et al., 2021)
XI.	Smart cities planning	Influence/3/GA + PS	Collaborate private and public sector collaboration	(Asmyatullin et al., 2020; Jong et al., 2019; Sidong et al., 2020)
XII.	Waste segregation, and landfill management	Control/2/GA	Update and integrate waste management system in all sectors	(Marsh and Steer, 2021; Reporter, 2014)

(continued on next page)

Table 2 (continued)

Category No. from highly recommended to lowly	Required action	Area of consideration/ Frequency/ Stakeholders	Strategy and Enforcement	References
XIII.	Lean manufacturing	Influence/2/GA + PS	Integrate researchers, businesses, government, and community	(AL-Shboul et al., 2018; Goshime et al., 2019)
XIV.	Stakeholder involvement via a multi-tier approach	Concern/1/GA + RS + PS	Integrate researchers, businesses, government, and community	Hemidat et al. (2022)
XV.	Laws regarding wastes	Influence/1/GA	Update and integrate waste management system in all sectors	Malaeb (2011)

responsible for the outcome of the activities, (iii) Area of concern: if the stakeholders have limited control or influence for the practical implementation (this is the most challenging of the suggestions). The framework's third aspect helps understand each stakeholder's ability and better understand the roles each actor can reasonably be expected to have in the funding and implementation of SSWM change management.

4. Results and discussion

In this section, we delve into the data collation and components of the recommendations identified in the 95 included publications on sustainable and efficient waste management. Table 2 summarizes the necessary actions, stakeholders, strategy, and enforcement required to achieve these goals. We also discuss the results in detail, highlighting the recommendations found in the articles by splitting them into 15 categories by grouping similar recommendations.

4.1. Data collation and components

Table 2 provides an overview of the recommendations identified in the 95 included publications. A more detailed description of the data from the literature is in Table S1. The tables highlight the necessary actions, stakeholders, strategy, and enforcement to achieve a more sustainable and efficient waste management system. The contribution of the framework and the table results is synthesizing many expert recommendations then analyzing those to enable better-informed decision-making. The results support policymakers, researchers, and stakeholders in developing and implementing effective waste management strategies. Section 4.2 discusses the results in detail. Table 2 also lists the recommendations in the studied articles, including using sustainable technology for waste diversion, controlling consumerism and wastage, and utilizing indicators and tools for environmental efficiency. As described in the methodology, Table 2 is organized into three columns: Required Action, Area of consideration/Frequency/Stakeholders, and Strategy and Enforcement. The first column - Required Action - lists the necessary actions to implement these recommendations, such as awareness campaigns, data collection, and resource management. The second column lists the stakeholders' spheres of control, influence, and concern and their frequency of mention in the systematic review process. The stakeholders include government agencies (GA), researchers and scientists (RS), and the private sector (PS). These are respectively defined as follows:

- (i) Government agencies (GA): Government agencies play a critical role in society, with various departments responsible for various aspects of society's functioning. Government agencies are responsible for implementing policies and regulations related to solid waste management and ensuring their enforcement. The five departments mentioned here - the Ministry of Education and Higher Education (MOEHE), the Ministry of Public Health (MOPH), the Ministry of Municipality (MME), the Ministry of Social Development & Family (MSDF), and the Ministry of Environment and Climate Change (MOECC) - are responsible for overseeing different domains in the society, ranging from education and health to the environment and municipality. They can make laws, regulations, and policies affecting people's lives and ensure their implementation.
- (ii) Researchers (RS): Researchers engage in systematic investigation to increase knowledge and understanding of a subject. Researchers are crucial in finding solutions and providing recommendations for better solid waste management practices. They conduct studies and research on various aspects of solid waste management, such as waste generation, collection, transportation, treatment, and disposal. In this study, the researchers are from Qatar University Education City Institutions, and Doha Institute of Graduate Studies. They play a critical role in creating new knowledge and solving societal problems. Their research findings can inform policymaking and decision-making by government agencies.
- (iii) Private sector (PS): The private sector is a key component of any economy responsible for providing consumer goods and services. In this study, the private sector is comprised three types of organizations: multinational corporations (MNCs), small and medium-sized enterprises (SMEs), and service providers (SPs). MNCs are large corporations that operate globally, while SMEs are smaller businesses that are usually locally owned. SPs provide services in various domains, including health, schools, restaurants, transport, and construction. The private sector plays a critical role in the economy by creating jobs, generating wealth, and providing essential social services. The private sector is an integral component of SWM, including companies

producing and distributing goods that ultimately become waste. The private sector significantly impacts SWM as it is responsible for generating waste and must adhere to government regulations and standards.

- (iv) The "Strategy and Enforcement" column refers to the actual actions to be carried out. It will be discussed in section 4.2, including recommendations for plans and strategies related to solid waste management. It broadly refers to the concrete steps taken to translate policies and ideas into reality.

4.2. Data analysis and interpretation

The recommendations from the 95 articles were grouped into 15 categories. The categorization allocation is purely based on the recommendations mentioned in the articles rather than the previously published paper that divided the literature according to the subject/objective into ten themes (Mariyam et al., 2022). The following discussion will describe the categories – in the order of decreasing frequencies from the SLR listed in Table 2. The first category, which received the most recommendations, was related to better research and policy coordination. The second category, with the second-highest number of recommendations, was focused on a market for value-added-products from waste. The third category emphasized the importance of increasing specific research areas or topics to achieve SSWM. The fourth category highlighted the need for awareness campaigns, while the fifth category focused on private-sector training and governance. The sixth category emphasized the importance of plastic recycling and a profitable market. The seventh category discussed the impact of mega events on waste management, and the eighth category contained miscellaneous and less frequent recommendations. The following paragraphs will elaborate on these categories and recommendations.

Research-policy Coordination: Out of the 95 articles reviewed, 17 recommendations were related to the need for better research and policy coordination. These suggestions encouraged conducting wide-ranging research on waste resource utilization using technologies and lessons from past experiences to develop practical solutions for Qatar's various economic sectors. The recommendations also called for institutions like Hamad International Airport and Qatar University to accelerate their sustainability initiatives in developing national waste recycling and management strategies. This includes utilizing construction wastes and integrating research efforts conducted by universities in Qatar with Ashgal, responsible for constructing and maintaining roads. It is important to take a holistic approach to efficient waste management using cleaner technologies, composting, and recycling, which requires the integration of researchers, businesses, the government, and the community.

Waste to value market: The second most suggested recommendation was a cluster of suggestions for producing value from waste (15 out of 95 articles). In addition to implementing the technology available in the country, one of the main challenges in this area is a lack of a market to sell the products (supply and demand constraints). For example, significant research has been conducted on gasification and pyrolysis (mainly on a lab scale) to produce biochar, which has considerable potential for water treatment and agricultural applications. However, lacking a market within the country could demotivate waste management using cleaner technologies such as pyrolysis. The lack of motivation could also be due to other products, such as bio-oil and syngas (from pyrolysis and gasification), which could compete with the market's oil and gas market. Hence, the motivation to develop a market should solely focus on efficient waste management using these technologies and as an alternative to existing detrimental solutions (landfilling and incineration). Both the first and second most suggested recommendations are categorized in the area of concern in this study since it's a challenge and requires collaboration amongst multiple stakeholders to change.

Specific research areas encouragement: Although significant research has been conducted in the country in the past decade concerning the Qatar National Development Strategy (QNDS) and QNV 2030, the third most recommended increase specific research areas or topics to achieve SWM. The specific research areas require a multi-disciplinary approach between various university colleges or departments. Interdisciplinary collaboration between policy researchers and engineers is recommended to examine the feasibility of waste management strategies for the country. One specific research area that could benefit from such collaboration is developing a tool to address the issue of increasing food waste generation, focusing on finding technological, social, and economical solutions. To ensure the success of this research project, it should involve various entities within a university, leveraging the strengths of different disciplines. Such collaboration can produce the most effective solution for the country, and stakeholders can play a crucial role in facilitating it by providing grants and developing institutional strategies.

Awareness campaigns: The fourth highest recommendation reinstated the need for awareness campaigns (9 out of 95). While some studies discussed the need for awareness of consumerism in the communities, others recommended using an Islamic approach to ethically consuming resources. The awareness needs to extend to professional development vision for teachers, thereby holistically integrating sustainability values. The recommendation comes from studies that have realized the unsustainable food consumption patterns and wastage behaviour patterns in society, which can only be corrected by effective campaigning utilizing all stakeholders in different sectors. This suggestion is considered an area of control for the stakeholders.

Private sector training and ESG driven approach: The private sector's studies on supply chain management and governance revealed the fifth most important recommendation for efficient waste management. Private sector training incorporating an Environmental, Social, and Governance (ESG) framework can be beneficial. ESG evaluates a company's performance and sustainability based on environmental impact, social responsibility, and governance practices. It is increasingly important for investors and stakeholders to assess companies' long-term viability and potential for financial success. However, companies in Qatar must prioritize ESG adoption. The training should also focus on efficient resource management and reduction to enhance companies' environmental performance. This suggestion is an area of influence that the PS stakeholder can address by updating and integrating waste management into their governance.

Plastic recycling and market: Seven of the articles highlighted the importance of plastic recycling and a profitable market as the sixth most crucial recommendation. While it could be included in the "waste to value market" suggestion, the authors emphasized its

significance with a separate recommendation. There is a need for private sector competitiveness in recycled plastics or innovative alternatives to promote recycling. Moreover, addressing the low recycling rates requires a multidimensional approach. GA should consider these recommendations to address the issue effectively.

Lessons from hosting mega events: Six of the total articles discussed the impact of mega events on waste management. Qatar's preparation for hosting the 2022 FIFA World Cup involved significant development, including constructing road and railway lines. Some studies explored the utilization of waste generated during construction for aggregates. The World Cup was the first carbon-neutral tournament, with efficient waste management as part of its legacy. The interest in environmental sustainability and climate assurance during the bidding and execution of the tournament should extend to the national strategy. The lessons learned from mega events and related research can provide valuable information resources for building an efficient waste management solution for the country. Everyone involved, including GA, PS, and RS, should join to utilize and conduct sustainability-related projects. This suggestion is considered an area of control for the stakeholders.

Other miscellaneous recommendations: The final eight suggestions have frequencies less than or equal to 4. Four of the 95 articles suggested developing research ideas, such as using char for plant growth in greenhouse settings, carbon capture technology, and the techno-economic feasibility of fertilizers from waste. In addition, developing and employing tools for environmental efficiency indicators, particularly to achieve the SDGs, is significantly lacking in the country. While the former requires more effort from the research and private sectors, the latter requires effort from government agencies. A nationwide indicator is specific to the country should be developed to measure environmental efficiency, including waste management. Such indicators and tools are crucial for achieving the SDGs. While the former requires more effort from the RS and PS, the latter requires effort from the GA since an efficient nationwide indicator specific to the country is required. A few studies also discuss that effective waste management relies on accurate data, which requires the systematic collection, analysis, and sharing of research. Having up-to-date data is crucial for understanding the scope of the problem and developing appropriate solutions. Better research and development for efficient waste management can be achieved through easy and updated data collection. Two studies discuss the importance of sustainable smart city planning for the country's expanding urbanization, with valuable lessons to learn from other countries (like China) and existing projects in the region (like Abu Dhabi and Dubai). Landfill aversion and management are also crucial aspects of waste management, requiring sustainable technologies and re-engineering to treat accumulated waste. For effective waste management and economic development, the manufacturing industry should also establish lean institute awareness by applying appropriate tools and research. Two articles recommended stakeholder engagement in SWM and circular economy. One article proposed appointing responsible units within municipalities to enforce waste management laws. Stakeholder involvement in SWM is a complex issue that requires collaboration between researchers, businesses, the government, and the community. The government agency can take responsibility for appointing responsible units to enforce waste management laws. Both studies emphasized the importance of collaboration between different entities to address the waste management issue in the country.

Table 2 (strategy and enforcement) and the following discussion is on the practical implementation of the recommendations. The

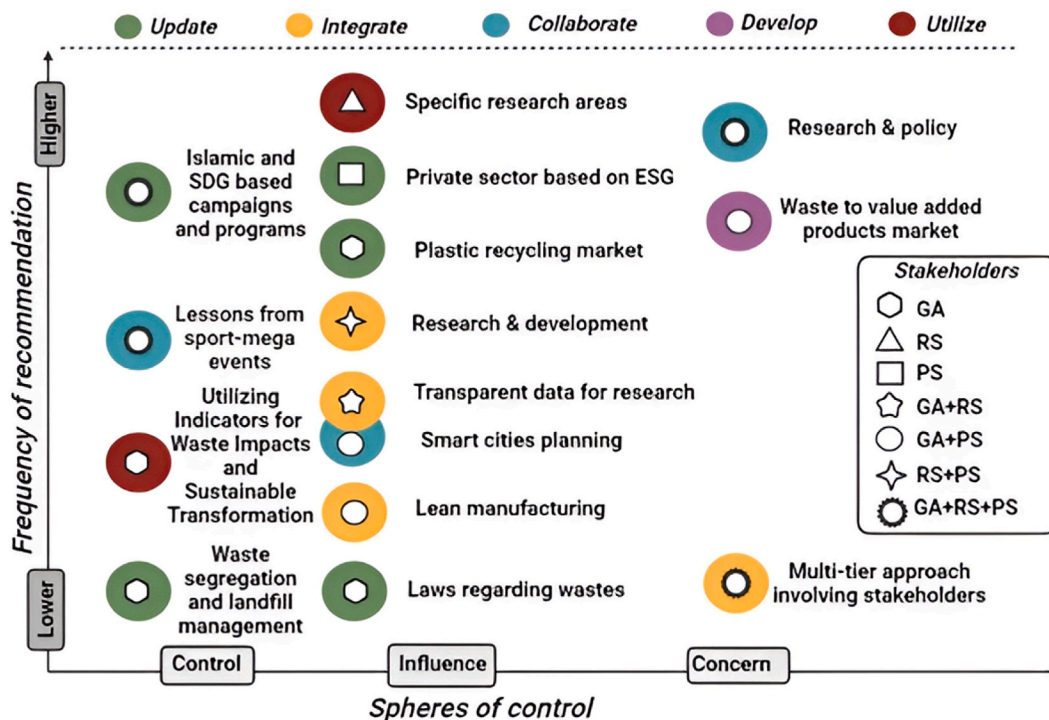


Fig. 2. A schematic summary of the policy recommendations and spheres of control.

following are the main practical implementations that the author suggested based on literature recommendations:

- i) Update and integrate the waste management system in all sectors: The goal is to improve the current system by updating it and integrating it across all sectors. This would help ensure that waste is managed effectively and sustainably.
- ii) Develop a market for circular economy: This means creating an environment where products made from waste can be sold, creating an economic incentive for waste management and reducing the amount of waste that ends up in landfills.

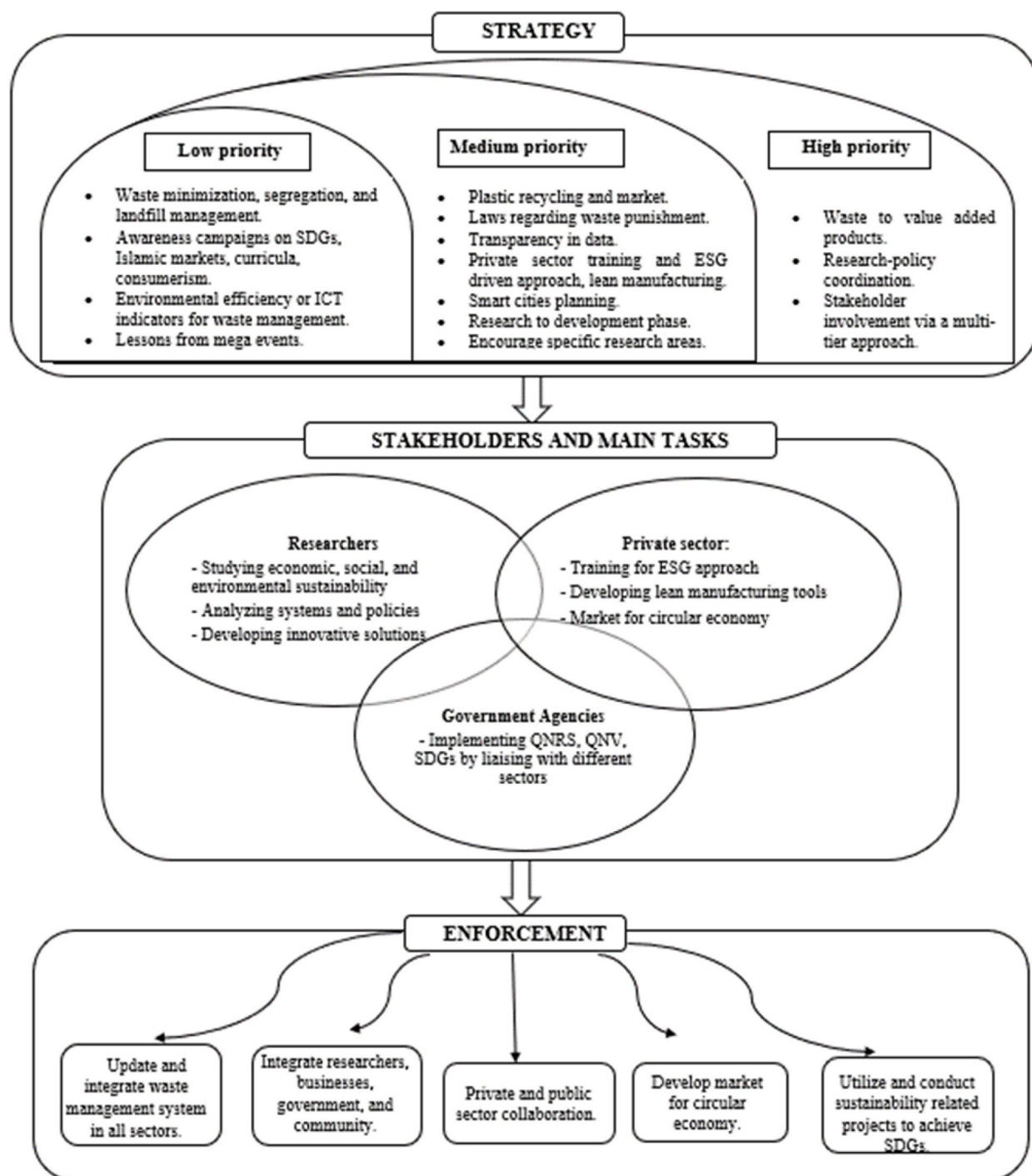


Fig. 3. SSWM thematic framework for the state of Qatar.

- iii) Utilize and conduct sustainability-related projects to achieve SDGs: By conducting projects related to sustainability, the goal is to help achieve the United Nations' SDGs, which aim to promote sustainable development and address global challenges such as poverty, inequality, and environmental degradation.
- iv) Integrate researchers, businesses, government, and community: This refers to collaboration and coordination among various stakeholders, including researchers, businesses, government agencies, and the community, to manage solid waste effectively.
- v) Collaborate with private and public sector collaboration: This refers to the need for cooperation between the private and public sectors to improve solid waste management. By working together, the private and public sectors can achieve better outcomes and achieve their goals more effectively.

5. SSWM framework – design, implementation and limitations

Fig. 2 visualises the information presented in Table 1, offering insights into the priority actions and stakeholders involved. The prioritization is based on the frequency of recommendations, with higher priority given to those suggested recurrently. Different colors signify the five main strategies, while various shapes represent distinct stakeholders. The figure distinctly highlights three critical areas of concern, with research and policy coordination emerging as the highest priority due to its frequency. This graphical representation plays a crucial role in guiding the framework development discussed in this section.

Considering the extensive data analysis, a unified framework encapsulates suggestions, stakeholders, strategies, and enforcement. Fig. 3 presents a schematic depiction of this comprehensive framework. The strategy is intricately linked to the spheres of control, influence, and concern, each corresponding to low, medium, and high priorities. Key stakeholders, namely RS, GA, and PS, are entrusted with implementing recommendations in 15 main categories (as illustrated in Fig. 2). The framework succinctly outlines the primary responsibilities of each stakeholder, emphasizing a holistic approach that necessitates efficient collaboration among them. Researchers are urged to continuously study sustainability from diverse perspectives, contributing innovative solutions by rigorously analyzing systems and policies, crucial for the success of SSWM. Such an approach was suggested by (Radwan et al., 2021) in a waste management study in Saudi Arabia. Adapting best practices to local environments and cultural circumstances outside of Saudi Arabia emphasizes the need for context-specific solutions. This recognizes that a one-size-fits-all approach may not be effective, and efforts should be tailored to the unique characteristics of the local environment and culture. Another review also concluded that to address cumulative issues in developing countries, a collaborative effort involving the general population, stakeholders, and governmental and non-governmental (NGO) entities are required to strengthen current waste management facilities (Khan et al., 2022b). Similarly, identifying optimal technologies for various scenarios will require concrete strategies, perspectives, and roadmaps. For example, widespread adoption of these waste-to-energy technologies will depend on economic incentives and supportive governmental policies (Khan et al., 2022a).

Implementing the QNV 2030 requires effective collaboration between researchers and the private sector, involving activities such as developing specific plans, allocating resources, establishing regulations or guidelines, and monitoring progress. While enforcement represents the culmination of efficient SSWM, effective communication between stakeholders is the initial step. The final segment of the framework incorporates enforcement mechanisms to ensure SSWM in Qatar, encompassing the five main criteria discussed as practical implementation in Table 2. This comprehensive framework provides a strategic guide for coordinated efforts among stakeholders to achieve sustainable waste management goals in Qatar.

The proposed framework unfolds a strategic approach to SSWM in Qatar that aligns priorities, engages key stakeholders, and emphasizes robust enforcement measures. At its core, the strategy prioritizes actions based on urgency and significance, categorizing them into low, medium, and high priorities.

Low Priority Strategies encompass foundational aspects such as waste minimization, segregation, and landfill management. These initiatives lay the groundwork for the broader strategy, setting the stage for awareness campaigns on SDGs, Islamic markets, curricula, and consumerism. Environmental efficiency and the integration of Information and Communication Technology (ICT) indicators for waste management are introduced, drawing lessons from mega events to inform future practices.

Medium-priority strategies delve deeper into operational aspects, including plastic recycling, legal frameworks for waste punishment, and transparency in data. The private sector assumes a pivotal role, undergoing training for an ESG approach, embracing lean manufacturing, and contributing to the development of circular economies through market initiatives. Smart city planning, transitioning from research to development, and targeted research encouragement round out this tier.

The High Priority Strategies elevate the framework by focusing on transformative actions. The emphasis is placed on converting waste into value-added products, fostering research-policy coordination, and adopting a multi-tiered stakeholder involvement approach. These high-priority strategies underscore the framework's commitment to innovation, collaboration, and holistic sustainability.

To implement the strategies, there are three key stakeholders - RS, PS, and GA-who are crucial in executing the strategic priorities. The RS, is primarily driven by their core tasks, delve into economic, social, and environmental sustainability, analyze systems and policies, and continuously develop innovative solutions. The PS assumes responsibility for training in ESG approaches, developing tools for lean manufacturing, and actively participating in circular economy markets. Most importantly, GA is pivotal in implementing national strategies liaising with different sectors to align initiatives with the QNRS, QNV and SDGs.

Finally, the enforcement measures encapsulate the essence of the framework, ensuring its practical implementation and sustained impact. These include updating and integrating waste management systems across all sectors, fostering collaboration among researchers, businesses, government, and the community. The creation of a circular economy market stands out as a pivotal enforcement action, reinforcing the shift towards sustainable practices. The framework emphasizes utilizing and conducting sustainability-related

projects as a means to achieve the SDGs.

In contemplating the significance of our findings, we recognize the pivotal interrelationship between the results obtained and the sustainable development paradigm. Our study has brought to light the existing challenges and barriers that hinder progress towards SSWM. [Table S1](#) describes some important barriers, including but not limited to challenges in facility management for efficient resource utilization, the need for quantifying and controlling medical waste, human and organizational factors impacting food waste reduction, communication gaps regarding the benefits of environmental initiatives for firms, and complexities in integrating environmental management with social and governance aspects. Understanding the real-world consequences of these findings becomes imperative to chart a path for tangible change and improvement, and our framework helps guide the pathway. Looking ahead, this study lays the groundwork for several promising avenues of research. Future investigations could delve deeper into the nuanced dynamics of waste-to-value processes, exploring innovative technologies such as pyrolysis and their applicability in the local context. Additionally, the identified priority areas warrant in-depth exploration, particularly the high-frequency recommendations of research-policy coordination and stakeholder involvement. As the waste management landscape evolves, ongoing research can uncover evolving challenges and propose adaptive strategies.

In the realm of SSWM, neo institutional theory emphasizes the role of isomorphic factors in shaping firms' environmental accountability practices. As proposed in the literature, the implementation of Environmental Management Accounting (EMA) techniques acts as a catalyst, influencing firms to adopt responsible environmental practices ([Amoako et al., 2021](#)). Isomorphic factors, including regulatory requirements and industry norms, exert a necessary influence, compelling organizations to align their operations with sustainable waste management standards. Additionally, institutional pressures play a pivotal role in enhancing the effectiveness of proactive environmental strategies, influencing facets such as innovative capabilities, market competitiveness, and reputation ([Daddi et al., 2016](#)). This dual perspective underscores the multifaceted impact of neo institutional theory on SSWM, offering a comprehensive understanding of the interplay between external influences and organizational practices in the pursuit of environmental sustainability.

The authors have realized some under-researched areas not mentioned in the analyzed literature and discussed previously in this study. The perspective of waste management research needs a shift; waste management is not just a technical issue; it also involves social and behavioral factors. The complex nature of the population residing in Qatar and the associated waste generation trends need to be investigated. Awareness campaigns and efficient management only arise when the demographic is understood in detail. Research could investigate how to increase public awareness and engagement in waste reduction and recycling and identify ways to promote sustainable waste management practices among households and businesses.

Additionally, the research could evaluate the environmental impacts of different waste management strategies, including the greenhouse gas emissions associated with waste disposal, and identify ways to minimize those impacts; a comprehensive life cycle study of municipal SWM is necessary. There are specific wastes that need attention, including hazardous wastes and electronic wastes. Hazardous waste can include industrial chemicals, pesticides, medical waste, electronic waste, and radioactive wastes; there are no studies discussing the generation of such wastes and their risk assessments, efficient treatment and disposal methods, regulation and policy (including enforcement), and emerging hazard including nanomaterials, e-wastes and contaminants in water and soil ([Srivastav et al., 2023](#)). There are no specific studies detailing the e-waste issue in Qatar; it is a growing global problem, but there is still limited research on the health and environmental impacts and the most effective ways to manage and recycle them. On the other hand, although food waste is a better-studied subject, there is still limited research on the causes and impacts of food waste in Qatar, especially in the supply chain. Finally, the concept of a circular economy, where waste is minimized, and resources are reused or recycled, is gaining momentum globally. However, there is still a lack of research on the feasibility, challenges, and benefits of implementing a circular economy on a large scale in the State of Qatar.

A crucial facet that merits explicit discussion is the social impact of our research. Beyond the technical and strategic aspects, the implications of improved SSWM extend into the fabric of society. Effective waste management influences public health, environmental well-being, and community resilience. By integrating social impact considerations, we underscore the broader implications of our recommendations on the lives of individuals and the communities they inhabit. Recognizing the social dimensions of waste management is integral to fostering a sense of responsibility and ownership among the public.

Implementing the proposed framework involves collaborative efforts from researchers, private sectors, and government agencies. Practical steps include updating and integrating waste management systems, fostering collaboration among diverse stakeholders, and establishing circular economy markets. Emphasizing integrating sustainable practices into everyday life, such as the PS adopting lean manufacturing and circular economy initiatives, is key to actualizing change in the observed situation.

In essence, our study not only provides a snapshot of the current state of waste management in Qatar but also paves the way for future endeavors and underscores the profound social impact that strategic improvements in SSWM can have on the broader community. We aspire to catalyze meaningful change and contribute to a more sustainable and resilient waste management ecosystem by weaving together the future scope, social impact, and real-world implementation considerations.

Also, to be considered in this review are the limitations of this study. Firstly, the framework is developed based on a systematic review process, which relies on the availability of data and information on the topic. A lack of data and information on the current state of SWM in Qatar in the published literature could limit the ability to make informed decisions on improving the situation. Additionally, understanding the attitudes and beliefs of the local population is crucial in understanding if the framework is practical. An SSWM framework can involve significant technical and operational challenges. If the necessary infrastructure, equipment, and personnel are unavailable, it may be impossible to implement the framework fully; this is a hurdle in ensuring what many studies suggested. There also may be resistance to change from stakeholders who are used to current waste management practices. Overcoming this resistance may be a challenge in implementing a new framework. Finally, a lack of effective enforcement and monitoring mechanisms could limit

the effectiveness of an SSWM framework. Ensuring the framework is implemented correctly and followed is crucial for its success.

6. Conclusion and future direction

Improper sustainable solid waste management (SSWM) poses significant health and environmental risks, and the Gulf Cooperation Council (GCC) countries, including Qatar, generate more waste than the global average per capita, with underdeveloped recycling sectors in the region. In light of this context-specific need for SSWM in Qatar, the reviewed study focused on collating recommendations and prospects for a thematic framework for the first time. Based on recurring suggestions in the studied literature, the prioritized recommendations highlighted the critical need for better research and policy coordination and the importance of creating value from waste and exploring specific research areas. Important aspects, such as interdisciplinary collaboration, awareness campaigns, and private sector involvement, were also identified. This study emphasized integrating researchers, businesses, the government, and the community to achieve efficient waste management using cleaner technologies, composting, and recycling.

However, the study acknowledged limitations due to the lack of updated data and information in the published literature. Future work should understand the attitudes and beliefs of the local population and overcome technical and operational challenges. Infrastructure, equipment, and personnel are essential for efficient SSWM. The study also highlighted potential obstacles such as resistance to change, ineffective enforcement and monitoring mechanisms, and the need to address specific waste types like hazardous and electronic waste, that requires specific attention in the future. The study also emphasized the importance of increasing public awareness and engagement in waste reduction and recycling, evaluating the environmental impacts of different waste management strategies, and exploring the feasibility and benefits of implementing a circular economy at a larger scale. Considering the proposed thematic framework, constant improvement in enhancing waste management is needed to address these gaps, and developing comprehensive solutions for SSWM in Qatar can be achieved effectively.

CRediT authorship contribution statement

Sabah Mariyam: Conceptualization, Formal analysis, Methodology, Writing – original draft, Writing – review & editing. **Logan Cochrane:** Conceptualization, Writing – review & editing, Supervision, Writing – original draft. **Tareq Al-Ansari:** Writing – review & editing. **Gordon McKay:** Supervision, Writing – review & editing.

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.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.envdev.2024.100986>.

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