Journal of Sustainable Software Engineering and Information Systems
Volume 2, Issue 2, 144-166.
e_ISSN: 3123-3007
https://e-journal.gomit.id/jsseis
DOI: 10.58723/jsseis.v2i2.262

Prioritizing Sustainability Requirements in Public Sector Information Systems Using an Integrated AHP–Fuzzy TOPSIS Framework

Omole Ezekiel Olaoluwa
Federal University of Technology, NIGERIA

Jeni Fitria
University of Bengkulu, INDONESIA

Oluwadarasimi Olowe
Lead City University, NIGERIA

Uddagiri Sirisha
Prasad V. Potluri Siddhartha Institute of Technology (PVPSIT), INDIA

Kishore Konda Chidella
University of Nevada Las Vegas, USA

*** Corresponding author:**
Jeni Fitria, University of Bengkulu, INDONESIA. ✉jefitria@gmail.com

Article Info

Article history:
Received: October 16, 2026
Revised: November 06, 2026
Accepted: November 18, 2026

Keywords:
E-Government
Green Requirements Engineering
Multi-Criteria Decision Making
Public Sector Information Systems
Sustainability Requirements

Abstract

Background: Public-sector information systems increasingly require sustainability considerations to be integrated into requirements engineering and project decision-making. However, prioritizing sustainability requirements remains challenging because environmental, economic, and social objectives must be balanced with financial constraints, regulatory obligations, and public-service priorities.

Aims: This study aims to develop and validate a multi-criteria decision-making framework for systematically prioritizing sustainability requirements in public-sector information system projects. The framework is designed to support transparent, consistent, and evidence-based decisions that reflect diverse stakeholder perspectives.

Methods: The proposed framework integrates the Analytic Hierarchy Process (AHP) and Fuzzy Technique for Order Preference by Similarity to Ideal Solution (Fuzzy TOPSIS). AHP is used to determine the relative weights of environmental, economic, and social sustainability criteria based on stakeholder judgments. Subsequently, Fuzzy TOPSIS ranks candidate sustainability requirements by accounting for uncertainty and subjectivity in stakeholder evaluations. The validation methodology incorporates case studies, consistency assessment, sensitivity analysis, and robustness analysis to examine the framework's applicability, reliability, and stability under varying criteria weights and evaluation conditions.

Results: The current study presents the proposed decision-making framework and its validation methodology. Empirical findings are not yet available; therefore, the framework's effectiveness and practical performance remain to be established through subsequent validation.

Conclusion: The proposed framework provides a structured approach to prioritizing sustainability requirements in public-sector information system projects. By combining AHP and Fuzzy TOPSIS, it is intended to facilitate transparent prioritization, accommodate uncertainty in stakeholder judgments, and support balanced decisions aligned with sustainability objectives, financial limitations, regulatory requirements, and public-service needs.

To cite this article: Olaoluwa, Omole Ezekiel., Fitria, Jeni., Olowe, Oluwadarasimi., Sirisha, Uddagiri., & Chidella, Kishore Konda. (2026). Prioritizing Sustainability Requirements in Public Sector Information Systems Using an Integrated AHP–Fuzzy TOPSIS Framework. *Journal of Sustainable Software Engineering and Information Systems, 2*(2), 144-166. https://doi.org/10.58723/jsseis.v2i2.262

This article is licensed under a Creative Commons Attribution-ShareAlike 4.0 International License ©2026 by author/s

INTRODUCTION

Digital transformation positions information systems as vital components of public administration. The frequent use of electronic means to access public services has increased reliance on various electronic systems such as e-government, platform-based administration, systems for financial administration, public service portals, and integrated databases for service delivery, resource and service coordination, and performing everyday transactions (Sharma et al., 2021; Shokhjakhon & Komila, 2025). The negative impact of failure in public service information systems goes beyond the productivity of the affected organisation. Citizens' access to basic services, the transparency of administration, and the public's confidence in the government may be negatively impacted (Ikwuanusi et al., 2024; Wilonotomo et al., 2025). The quality of information systems cannot be assessed based on function, security, reliability, usability, and cost, as in the past. It is necessary to consider the systems' environmental impact, economic sustainability in the future, social inclusion, and their capability to support delivery of public services throughout their life cycle (Muciaccia & Tedeschi, 2023; Wu et al., 2018).

This is especially critical in the public sector where digital projects experience challenges due to scarce resources, regulatory frameworks, public scrutiny, procurement processes, and shifting policies (AlNuaimi et al., 2022; Ikwuanusi et al., 2024). Public Sector Systems address different users, stay active for long periods, interface with legacy frameworks, and provide accessibility, privacy, auditing, and transparency. Consequently, decisions made in the requirements engineering process may have long-lasting effects on the use of energy, cost of ownership, reliance by the institution on particular vendors, access to services, and the public's trust (Amend et al., 2021; Bambazek et al., 2023; Demi, 2020). Public Sector Digitalisation requires processes for making decisions that consider the other effects of these requirements, prior to their selection and implementation.

Software engineering sustainability involves analysing complex, indirect, and time-varying impacts of software systems. The Karlskrona Manifesto argues that sustainability should not be equated with just environmental sustainability. It should involve many orders of systems effects and interconnected dimensions (Ferrari et al., 2022; McGuire et al., 2023; Venters et al., 2017). Furthermore, different quality requirements impact the environment, economics, technology, and society in inconsistent ways, implying that their assessment in isolation should not be considered sufficient. In the context of public sector information systems, this study is concerned with environmental, economic, and social sustainability since these dimensions relate to the usage of resources, the financial viability of institutions, and the public value.

Environmental sustainability involves minimising the negative ecological impacts of developing, using, and disposing of information systems. This includes the use of energy-efficient software and hardware, implementing processes that result in a net decrease in paper consumption, minimising the carbon footprint, utilising resources in a conservative manner and planning the life-cycle of hardware (Abatan et al., 2024; Pazienza et al., 2024; Trkman & Černe, 2021). Economic sustainability is concerned with whether a system remains financially viable, can be easily maintained and is valuable throughout its lifetime. This is evident in the costs associated with development and use of the system, how efficiently it can be maintained and evolved, and whether it avoids excessive vendor lock-in. Social sustainability is concerned with whether the system supports trustworthy and equitable public services through digital inclusion, public transparency, stakeholder engagement, user protection and the development of public trust (Djatmiko et al., 2025; Lubis et al., 2024).

These dimensions should not be considered post-deployment impacts of secondary importance. Requirements articulate the expected properties of the system. They also affect system architecture and procurement options and impact the distribution of benefits and costs for the system stakeholders (Guizzardi et al., 2023; Kroll, 2021). Therefore, sustainability has to be articulated as requirements. Pre-existing catalogues and frameworks show the utility of broad sustainability concepts being converted into reusable goals and quality requirements.

Requirement's engineering offers the first more systematic approach to determine sustainability objectives and relate them to system functional operational decisions. Among other things, it captures environmental, economic, and social concerns; transforms these concerns into quantifiable requirements; captures stakeholder concerns; and addresses and resolves dependencies and

conflicts and justifies design and budgetary and procurement decisions (Shallcross et al., 2021). Embedding sustainability within requirements poses challenges. This is partly attributed to the manner in which sustainability is understood by practitioners. More fundamental, however, is the nature of the procedures in use, which favour addressing short-term rather than long-term effects.

Traditional thinking about requirement prioritisation often considers factors of demand and urgency, compliance, cost and effort of implementation, risk, and value. Such factors continue to hold. But these do not fully extend the basis of sustainability. For instance, requirements that incur higher implementation costs may over a period of years significantly reduce operational costs and energy consumption (Robati et al., 2021; Upadhyay et al., 2021). A requirement that facilitates implementation may furthermore increase operational complexity, inhibit the full and active participation of citizens with minimal digital capability, and create dependence on proprietary systems. Sustainable requirement engineering therefore needs to provide a mechanism to consider both the immediate constraints of the projects and the longer-term public impact (Bambazek et al., 2023).

Complexity arises when determining sustainability requirements due to multi-dimensional and often intersectional requirements that are evaluated by stakeholders with varying responsibilities and values. For instance, technical workers may prioritise requirements for performance, interoperability, maintainability, and efficiency, while public managers may prioritise requirements for affordability, legislation, continual service delivery, and accountability (Habibullah et al., 2023; Sun & Medaglia, 2018). Additionally, stakeholders representing the public may prioritise requirements for accessibility, transparency, and privacy, as well as inclusion and trust. These views are best represented by multiple costs and/or benefits rather than a single cost or benefit.

Moreover, trade-offs further complicate decision-making. For example, in the realm of infrastructure, requirements that increase efficiency of energy use may be more expensive to install. Requirements to provide open accessibility may increase the demand for security and the management of identities. Requirements for greater transparency may conflict with privacy and/or confidentiality. Requirements for the delivery of a service may be digitally based and may exclude a segment of the population that is lacking in either connectivity or digital literacy (Budd et al., 2020; Lubis et al., 2024). Longer-term requirements for maintainability may, in fact, necessitate greater design efforts and a longer time to deploy the infrastructure. Value priorities for sustainability requirements, when assessed by stakeholders, are expressed as being of low, moderate, important and very important, respectively. These assessments necessarily introduce uncertainty and may result in unstable rankings when precision is imposed (Choudhary et al., 2021; Harvey & Rabetti, 2024). Therefore, the best approach to prioritisation must cope with multiple criteria, different stakeholders, competing interests, and ambiguous assessments.

Multi-criteria decision-making is well suited to evaluate alternatives when no single alternative is the best on all criteria, and many criteria need to be considered. There are numerous requirements prioritisation techniques; however, there are still concerns pertaining to method selection, scalability, participation, and evaluation. The AHP is effective for decomposing a decision into a hierarchy and providing relative weights for criteria using a set of pairwise comparisons (Rojas & Macías, 2019; Svensson & Torkar, 2023). Fuzzy TOPSIS is able to rank alternatives and refine the criteria, respectively, using a set of paraphrased statements and a measure of the proximity of alternative solutions to the ideal and negative ideal solutions (Kukreja, 2022). Various studies in the last few years have shown that fuzzy AHP and fuzzy TOPSIS can be used to rank software requirements, and that the two techniques are dissimilar in their complexity and the resulting rankings (Lo et al., 2024; Nazim et al., 2022).

Therefore, this paper proposes an integrated AHP–Fuzzy TOPSIS framework. Within this integrated framework, AHP is used to evaluate the relative importance of the sustainability dimensions, criteria, and subcriteria. Fuzzy TOPSIS is employed to rank and evaluate the sustainability requirements of stakeholders. This integrated framework provides a systematic approach to sustainability requirement prioritisation and evaluation for public organisations.

Four gaps underpin this research. First, sustainable software research provides principles, models, metrics, and catalogues and offers some development guidance. However, these contributions do not

usually include an operational instruction for selecting among competing sustainability needs. Second, Green and Sustainable Requirements Engineering is useful in identifying sustainability needs and drafting them. However, the prioritisation (of needs) is dependent on either informal stakeholder bargaining or criteria related to the project. Third, in software engineering, the MCDM (Multiple Criteria Decision Making) approach has been used to address evaluating software and technology, vendor selection, and software quality, as well as the prioritisation of requirements or risks associated with a software development project. However, sustainability requirements for information systems in the public sector have been neglected. Fourth, very little empirical research integrates sustainability criteria in the economic, environmental, and social dimensions, includes the non-technical stakeholders, assesses real public sector requirements, judges the consistency of opinions and the robustness of the rankings, and compares the findings for more than one type of public information system. Thus, public organizations have no validated approach and no transparency in transforming multidimensional sustainability goals to legitimate priority requirements.

This study aims to develop and validate an integrated AHP–Fuzzy TOPSIS framework for prioritising sustainability requirements in public-sector information system projects. Specifically, it seeks to identify and validate sustainability criteria relevant to public-sector information systems; determine the relative weights of environmental, economic, and social criteria; rank sustainability requirements using the integrated model; compare the priorities assigned by technical and non-technical stakeholders; and evaluate the consistency, robustness, and practical applicability of the proposed framework.

The study addresses the following research questions:

RQ1. What sustainability criteria and subcriteria are relevant for prioritising requirements in public-sector information system projects?

RQ2. How do technical and non-technical stakeholders assign relative importance to environmental, economic, and social sustainability criteria?

RQ3. Which sustainability requirements receive the highest priority under the integrated AHP–Fuzzy TOPSIS model?

RQ4. How consistent and robust are the resulting priorities across stakeholder groups, case-study systems, and alternative weighting scenarios?

RQ5. To what extent is the proposed framework perceived as transparent, understandable, and applicable by public-sector stakeholders?

This study makes three principal contributions. Theoretically, it connects sustainable requirements engineering, MCDM, and public-sector information systems by treating sustainability as a decision concern embedded in requirements rather than as a post-implementation assessment. Methodologically, it develops an integrated procedure covering criteria validation, hierarchical weighting, fuzzy requirement scoring, ranking, consistency assessment, stakeholder-group comparison, and sensitivity analysis. Practically, it provides public organisations with a transparent decision-support framework for balancing sustainability objectives against financial constraints, regulatory obligations, implementation capacity, and public-service priorities. Through these contributions, the study seeks to strengthen the traceability and defensibility of sustainability-related decisions in government information-system projects.

METHOD

Research Design

This study used Design Science Research (DSR) within a multiple case study framework. DSR was most appropriate because it allows for the design and evaluation of an artefact, in this case a structured decision-support framework for the prioritisation of sustainability requirements in public sector information system projects (Humble & Mozelius, 2023; Olawumi & Chan, 2021). The multiple case study approach was used to test if the framework could be applied consistently across various

government information systems and within different government organisations. Combining the two frameworks allowed this study to consider the context of the public sector when making decisions.

The research process comprised eight steps: Problem definition, identification of sustainability criteria, validation of criteria and requirements, weighting of criteria using AHP, requirement ranking with Fuzzy TOPSIS, sensitivity and robustness, stakeholder assessment, and framework improvement (Behl et al., 2023; Pishchulov et al., 2019). During the problem definition step, the research team focused on the challenges confronting public organisations in balancing environmental, economic, and social matters against cost, regulatory, operational and service constraints. Subsequent to a review of policy documents, software requirement specifications, procurement documents, and discussions with domain experts, the sustainability criteria were identified (Bautista-Puig et al., 2022; Rocha et al., 2024).

The development, application and validation of the proposed framework is illustrated in Figure 1. The development phase established the sustainability dimensions, criteria, assessment hierarchy and decision procedures. The application phase involved the collection of requirements, weighting of the criteria and requirement ranking. The validation phase concerned the internal consistency, sensitivity, robustness, and the perceived usefulness and transparency of the framework.

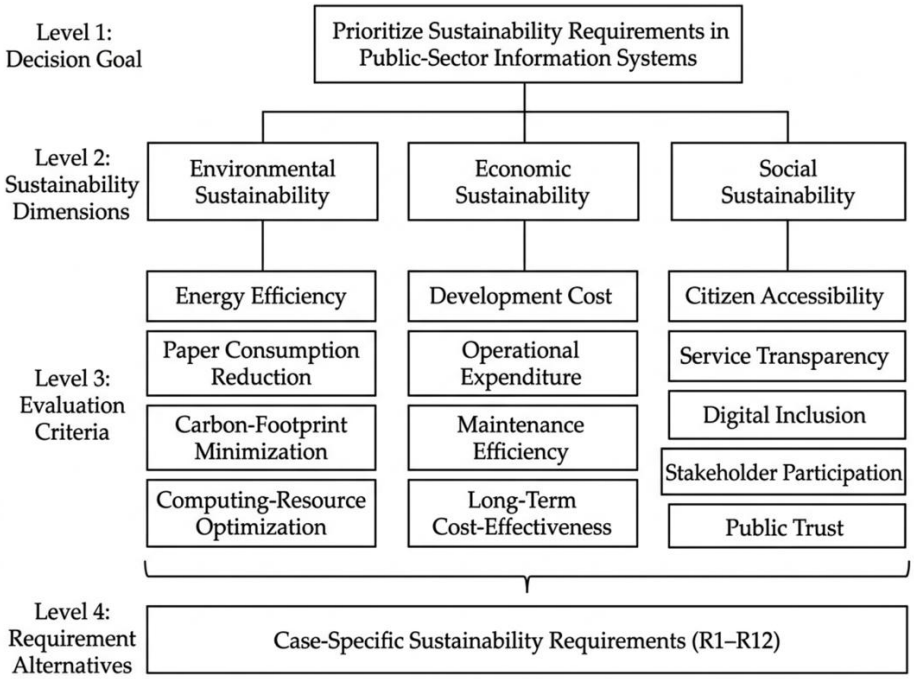


Figure 1. Research Design and Validation Stages of the Proposed Framework

As shown in Figure 1, requirements elicitation created the initial sustainability alternatives. AHP and Fuzzy TOPSIS methods transformed the pairwise comparisons and linguistic assessments of stakeholders into criteria weights, respectively. After that, sensitivity and robustness analyses were performed to check if ranking changed with different weightings, groupings of stakeholders, and contexts. The results of the evaluations helped clarify the criteria, modify the procedures for making decisions, and provide a better description of how to put the criteria into practice within the final framework.

Case-Study Context

The framework was evaluated through three public sector cases representing the variety of service purposes, stakeholder configurations, and sustainability challenges. Case A included an e-government service system for citizens to interact with local government agencies. It included several different services such as an electronic population registration system, electronic licensing, admission of public complaints, and a citizen service portal (Janowski et al., 2018; Sharma et al., 2021). The system was used by citizens, frontline public service personnel, system administrators,

and managerial decision-makers. Sustainability concerns for the system were expected to be related to digital inclusivity, accessibility, transparency of services, sustainable energy use, and public trust.

Case B included a digital public administration platform for internal use by government agencies. The platform supported services such as digital document management, web-based correspondence, personnel administration, and inter-agency data exchange. The primary users of the platform were administrative staff, managers, records officers, and information technology staff. Sustainability challenges for the platform were expected to be related to the use of paper, optimisation of storage resources, interoperability, long-term sustainability and flexibility, and avoiding vendor lock-in.

Case C centred on a government financial management system used for budgeting, procurement, monitoring of expenditures and revenues, and financial reporting. The system was used by finance officers, procurement staff, auditors, department managers, and senior government decision-makers. Principal sustainability challenges associated with the system included operational efficiency, transparency, audibility, data protection, long-term cost effectiveness, service continuity, and compliance with regulations.

For each case, details were recorded on the purpose of the system, the implementing agency, the status of development or modernisation, principal users, number and type of requirements, sustainability problems, and the regulation(s) that were applicable. To maintain confidentiality of the institutions, participating organisations were known by case labels that were not their formal names.

Participant and Stakeholder Selection

Purposive sampling was utilised for case selection since the study involved persons with understanding of public sector information systems and software requirements, public service processes, sustainability, and government decision-making. The stakeholders included software developers, system analysts, requirements engineers, IT and public service managers, financial and procurement officers, environmental and sustainability officers, decision-makers in government, and representatives of the citizen and/or the user community.

Participants were selected when they had developed, managed, evaluated, regulated, or used one of the information systems. They were also selected if they understood the system and the public service process and if they had other related experiences in government digitalisation. Experienced practitioners were selected to participate in the survey, expert assessment, and validation workshop. Participants who had limited understanding of the information systems were excluded from the requirement evaluation and pairwise comparison.

It was important to have both technical and non-technical stakeholder groups represented because sustainability priorities can be differentiated based on professional affiliations and organisational positions. Technical stakeholders were expected to make informed assessments of infrastructure, software quality, integration, performance, and usability. Non-technical stakeholders were expected to offer critical insights on affordability, inclusivity, feasibility, and value.

Table 1. Characteristics of Case-Study Systems and Participating Stakeholders

Case	Information system type	Organization	Project stage	Stakeholder group	Number of participants	Relevant experience
A	E-government service system	Municipal Digital Service Agency	Operational modernization	Technical stakeholders	12	6–12 years
A	E-government service system	Municipal Digital Service Agency	Operational modernization	Non-technical stakeholders	14	5–15 years
B	Digital public administration platform	Regional Administrative Secretariat	System integration and modernization	Technical stakeholders	11	5–11 years
B	Digital public administration platform	Regional Administrative Secretariat	System integration and modernization	Non-technical stakeholders	13	6–16 years

Case	Information system type	Organization	Project stage	Stakeholder group	Number of participants	Relevant experience
C	Government financial management system	Regional Financial Management Agency	Operational enhancement	Technical stakeholders	10	6–13 years
C	Government financial management system	Regional Financial Management Agency	Operational enhancement	Non-technical stakeholders	12	7–17 years

The distribution of the final participants was assessed to understand the sampling adequacy of technical, managerial, operational, regulatory, and citizen-focused viewpoints. Stakeholder characteristics were reported descriptively using frequencies, percentages, and relevant measures of professional experience. The distribution was also considered in assembling stakeholder-group rankings.

Identification of Sustainability Requirements

Candidate sustainability requirements were collected from software requirement specifications, project proposals, procurement documents, government digital-service policies, system evaluation reports, semi-structured interviews, and stakeholder workshops. Document analysis was used to identify sustainability requirements, functional, and quality requirements with environmental, economic, and social concerns.

The screening process consisted of five stages. First, candidate requirements were extracted and recorded in the requirements register. Second, duplicated or semantically equivalent requirements were merged. Third, vague or solution-specific statements were rewritten into consistent and testable requirement formulations. Fourth, each requirement was classified according to its primary sustainability dimension while its possible effects on other dimensions were retained. Fifth, the resulting list was reviewed by domain experts to assess relevance, clarity, measurability, and applicability.

Requirements are described using the responsible system, expected behaviour or property, sustainability goal and operational context. An example of an energy efficiency requirement is: “The system shall minimise unnecessary data-processing operations to lower energy consumption during routine service transactions.” Requirements that could not be evaluated consistently, were outside the authority of the participating agency, or duplicated mandatory regulatory obligations without a meaningful prioritisation decision were excluded. A requirement was retained if it achieved at least [80%] expert agreement regarding its relevance and clarity.

Sustainability Evaluation Hierarchy

The decision hierarchy contained four levels. Level one of the hierarchy expressed the goal of the overall decision: To prioritise sustainability requirements in public sector information systems. Level two of the hierarchy expressed the dimensions of sustainability: environmental, economic and social sustainability, respectively. Level three of the hierarchy expressed the evaluation criteria for each dimension. Level four of the hierarchy expressed the case-specific sustainability requirements as decisions to be made.

The environmental criteria consisted of the requirements to improve energy efficiency, reduce paper use, minimise carbon footprint and optimise use of computing resources. The economic criteria consisted of the requirements to reduce development costs, minimise operating costs, increase the efficiency of maintenance, and ensure long-term cost-effectiveness. The social criteria consisted of the requirements to increase the accessibility of services to citizens, increase transparency of services, increase digital inclusion, increase stakeholder participation and increase public trust. Figure 2 illustrates the breakdown of the decision objective into the sustainability dimensions, evaluation criteria and requirement alternatives. This hierarchy provided the structure for stakeholder judgements considering the varying requirements for each case.

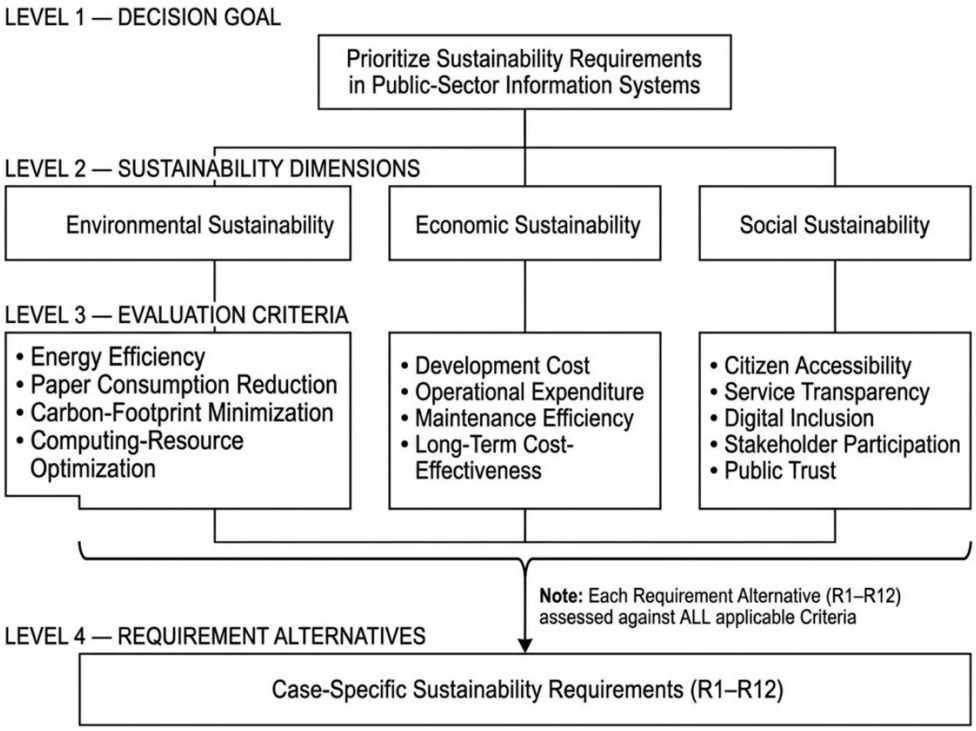


Figure 2. Hierarchical Structure of Sustainability Requirement Prioritisation

Each requirement was assessed across all dimensions instead of just the sustainability dimension it was initially placed in. Evaluating across dimensions mitigated the risk of prioritising a single dimension of sustainability in the final ranking. For instance, the requirement for energy-efficient infrastructure can also consider the cost of development, the efficiency of maintenance, the reliability of service, and the long-term value to the public.

Operational definitions were developed prior to the stakeholder assessment in order to minimise interpretation differences. Dimensions, criteria, operational definitions, measurement instruments, and evaluation scales of the framework are presented in Table 2.

Table 2. Sustainability Dimensions, Criteria, Operational Definitions, and Measurement Indicators

Dimension	Criterion	Operational definition	Example indicator	Assessment scale	Supporting source
Environmental	Energy efficiency	Extent to which the requirement reduces energy consumed during system operation	Estimated reduction in processing or infrastructure energy use	Very Low–Very High	Sustainable software literature
Environmental	Paper consumption reduction	Contribution to reducing paper-based administrative processes	Percentage of processes converted to validated digital workflows	Very Low–Very High	Green information systems literature
Environmental	Carbon-footprint minimization	Potential contribution to reducing direct or indirect greenhouse-gas emissions	Estimated emissions reduction from infrastructure or service delivery	Very Low–Very High	Green computing literature
Environmental	Computing-resource optimization	Efficient use of processing, storage, network, and hardware resources	Reduction in storage, processing, or hardware requirements	Very Low–Very High	Software efficiency literature
Economic	Development cost	Financial resources required to implement the requirement	Estimated design, development, acquisition, and integration cost	Very Low–Very High cost	Project cost records

Dimension	Criterion	Operational definition	Example indicator	Assessment scale	Supporting source
Economic	Operational expenditure	Effect on recurring costs during system use	Annual hosting, licensing, staffing, and support expenditure	Very Low–Very High cost	Agency operational records
Economic	Maintenance efficiency	Contribution to reducing corrective and adaptive maintenance burden	Estimated maintenance effort or change complexity	Very Low–Very High benefit	Software maintainability literature
Economic	Long-term cost-effectiveness	Balance between life-cycle costs and expected organizational or public benefits	Total cost of ownership and expected long-term value	Very Low–Very High benefit	Life-cycle evaluation literature
Social	Citizen accessibility	Extent to which diverse citizens can access and use the service	Compliance with accessibility and multi-channel service standards	Very Low–Very High	Digital accessibility standards
Social	Service transparency	Contribution to visibility, traceability, and accountability of public processes	Availability of status tracking, explanations, and audit trails	Very Low–Very High	E-government literature
Social	Digital inclusion	Ability to prevent exclusion based on disability, income, location, literacy, or connectivity	Availability of assisted, low-bandwidth, and inclusive service options	Very Low–Very High	Digital inclusion literature
Social	Stakeholder participation	Extent to which affected groups can contribute to system decisions	Number and diversity of stakeholder participation mechanisms	Very Low–Very High	Participatory design literature
Social	Public trust	Potential to strengthen confidence in the security, fairness, reliability, and legitimacy of the system	Stakeholder perception or trust-evaluation score	Very Low–Very High	Public administration literature

The final sample included 72 participants across the three case study systems. Case A included 26 participants, Case B included 24 participants, and Case C included 22 participants. Thirty-three participants represented technical stakeholder roles, while 39 represented public-service managers, financial and procurement personnel, government decision-makers, and user representatives. Relevant professional or service-related experience ranged from 5 to 17 years. This sample helped to define a representative cross-case balance of the technical, managerial, operational, financial and citizen domains. The stakeholder balance provided sufficient separation of technical and non-technical stakeholder groups for criteria weighting, requirement ranking, and cross-group validations.

AHP-Based Criteria Weighting

We used AHP to determine the relative importance of sustainability dimensions and criteria. Participants were asked to rate the relative importance of each pair of elements at the same hierarchical level on the nine-point scale. Importance values were measured on a ratio scale. The judgements between the extreme category values were represented using the intermediate values, i.e. 2, 4, 6, and 8. A value was automatically reverse scored if the preference direction was reversed.

Individual pairwise comparison matrices were aggregated by using the geometric mean. For a group of (K) participants, the aggregated comparison between criteria (i) and (j) was calculated as:

$$a_{ij}^{G} = \left(\prod_{k=1}^{K} a_{ij}^{(k)} \right)^{1/K}$$

Local criteria weights were obtained by normalising the geometric means of the matrix rows. Global weights were calculated by multiplying the local criterion weight by the weight of its parent sustainability dimension.

The consistency of each comparison matrix was assessed using the consistency index and consistency ratio:

$$CI = \frac{\lambda_{\max} - n}{n - 1}$$

$$CR = \frac{CI}{RI}$$

where (λ_max) is the principal eigenvalue, (n) is the matrix order, and (RI) is the corresponding random index. A consistency ratio below 0.10 was treated as acceptable. Participants whose judgments exceeded this threshold were given an opportunity to review the inconsistent comparisons without being directed toward any preferred response. The analysis reported local weights, global weights, principal eigenvalues, consistency indices, and consistency ratios for the full participant group, technical stakeholders, non-technical stakeholders, and each case-study system.

Fuzzy TOPSIS-Based Requirement Ranking

Fuzzy TOPSIS was chosen to rank the sustainability criteria, as stakeholders may prefer to assess complex criteria through linguistic terms compared to precise numerical terms. Five linguistic terms were used: Very Low, Low, Medium, High, and Very High. These linguistic terms were represented by triangular fuzzy numbers in this order: Very Low (0.00, 0.00, 0.25), Low (0.00, 0.25, 0.50), Medium (0.25, 0.50, 0.75), High (0.50, 0.75, 1.00), and Very High (0.75, 1.00, 1.00).

To develop a fuzzy decision matrix, the stakeholder ratings were collected and consolidated. Additionally, the matrix was normalised in order to address the inconsistencies that may exist between the benefits and costs criteria. For the benefit criteria, higher ratings were considered to be more preferable sustainability outcomes, whereas for the cost criteria (development cost and operational expenditure), lower ratings were considered to be more preferable. The weighted fuzzy decision matrix was obtained by multiplying the normalised matrix by the Global AHP weights.

The fuzzy positive ideal solution represented the best attainable performance across all the criteria, whereas the fuzzy negative ideal solution represented the worst performance across all the criteria. The distance of each requirement from the two ideal solutions was calculated using the vertex distance method. The closeness coefficient of the requirement (i) was calculated as follows:

$$CC_i = \frac{D_i^-}{D_i^+ + D_i^-}$$

The higher the closeness coefficient of a requirement, the higher the requirement was ranked. From the highest ranked to the lowest ranked requirements, the results were grouped into the critical, high, moderate and low requirements, based on their importance to guide practical decisions.

Integration of AHP and Fuzzy TOPSIS

As part of a sequential analytical process, both methods were integrated. The global criteria weights generated by the AHP method were incorporated in the Fuzzy TOPSIS method along with stakeholder evaluations of the candidate requirements. This process defined the following analytical sequence:

global criteria weights → fuzzy stakeholder ratings → weighted fuzzy decision matrix → ideal solution distances → closeness coefficients → final requirement ranking.

AHP was not used to compare all requirements in pairs because the number of requirements could potentially produce a high number of pairwise comparisons, resulting in an undue burden and

increasing inconsistency. For the purpose of developing an efficient method, while remaining confident in the stakeholder judgments, Fuzzy TOPSIS was used to rank the alternatives.

Model Validation

Internal consistency, sensitivity analysis, cross-group validation and practical validation were used to test and evaluate the model. Internal consistency validation was concerned with whether the pairwise comparisons satisfied the AHP consistency threshold. Sensitivity analysis examined whether the ranking was maintained after the relative weights of the environmental, economic, and social dimensions were changed.

Four cases were investigated. In the environment-dominant case, the greatest weight was assigned to environmental concerns. In the cost-constrained case, the emphasis was placed on development and operational affordability. The case of social inclusion placed weight on accessibility, inclusion, participation, and trust. The balanced sustainability case placed the three dimensions in the same order of importance.

Cross-group validation analysed how rankings generated by technical, non-technical, management and user/citizen stakeholder groups compared. Practical validation was performed through stakeholder workshops, where participants assessed the clarity and transparency of the framework and evaluated the perception of fairness, ease of use, and overall utility and gauge their implementation. This was done by answering a series of questions to identify their level of agreement, followed by an open comment section.

Robustness Analysis

The robustness of rankings was analysed using Spearman's rank correlation coefficient, changes in the highest ranked requirements, variability of closeness coefficients, systematic weight perturbation, cross-case and stakeholder subgroup analyses. Spearman's rank correlation was employed to measure the resemblance of the baseline ranking and each alternative ranking. To assess requirement rank stability, the number of requirements that were consistently ranked within the top 3 or top 5 across all scenarios was determined.

A requirement was considered robust if it consistently ranked within the same range, stayed within the same closeness range, and maintained the same priority. Requirements exhibiting large rank reversals were investigated to understand the cause of the rank instability, whether it was driven by a change in weights or caused by a change in stakeholder groups.

Ethical Considerations

The participation of study subjects was voluntary, and informed consent was obtained from all participants before data collection. Participants were informed about the goal of the study, the procedures that would be adopted, the intended use of the study information, the confidentiality measures put in place, and the right to withdraw from the study at any time without consequence. In the research records, the participants' identifying information was removed, and participants were represented by code during data processing and reporting.

Some information was evaluated as being of an institutional or project nature, and it was deemed confidential. Restricted procurement information, security-related system specifications, internal access credentials, and other sensitive government documents were excluded from publication. Survey, expert-assessment, and workshop findings were reported only in aggregated form to minimise the possibility of identifying individual participants or participating organisations.

The study was conducted in accordance with generally accepted principles for research involving professional participants and organisational stakeholders. Permission to conduct the research and access relevant non-confidential project information was obtained from the participating organisations prior to data collection. Because the study focused on professional judgments concerning information-system requirements and did not involve clinical interventions or the collection of sensitive personal data, all research procedures emphasised informed participation, confidentiality, data protection, and responsible use of organisational information in accordance with applicable institutional research policies.

RESULTS AND DISCUSSION

Results:

Characteristics of the Cases and Stakeholders

Three information system case studies from the public sector were evaluated empirically. The case studies represented citizen-facing, administrative, and financial-management systems. Case A focused on an operational modernisation of an e-government service system. Case B centred on the integration and modernisation of a digital public administration system. Case C focused on the enhancement of a government financial management system. Having a variety of case studies allowed the framework to be assessed for different service objectives, user groups, operational limitations, and sustainability challenges.

Thirty-one original sustainability-related requirement statements were derived from requirements and project documents, procurement documents, policy documents, interviews, and participant workshops. Through deduplication and semantic grouping, these statements were condensed to 15 candidate requirement families. After expert review, 12 requirement families constituted the final prioritisation sample. Three candidate requirements were removed as they either included a broader, more measurable requirement, did not involve measurable requirements across the three systems, or represented a generic legal requirement as opposed to a prioritised sustainability requirement.

The sample had 33 technical stakeholders and 39 non-technical stakeholders (the 72 participants had 26 from Case A, 24 from Case B, and 22 from Case C). Participants had 5 to 17 years of relevant professional or service experience, with a mean of 9.8 years (SD = 3.1). In the sample, 21 participants had 5 to 7 years of experience, 33 had 8 to 12 years, and 18 had 13 to 17 years. Sixty-one participants (or 84.7 per cent) completed one or more of the validation workshops as well as the structured assessments.

The case contexts influenced the sustainability issues that surfaced during elicitation and validation. Case A stakeholders related sustainability to citizens' continued access to the service, a low-bandwidth version of the service, service transparency, and the inclusion of people with varying levels of digital skill. Case B emphasised digitisation of documents, resource optimisation, service interoperability, and other goals such as design, construction, and operation of services that would minimise or eliminate repetitive work processes. Case C stressed auditability, operational service continuity, maintenance, and optimisation of service transparency and control of service costs over extended periods. These differences indicated that in the public services context, a common evaluation set would not change the ranking of the case for how the evaluation should prioritise the issue of sustainability.

Validated Sustainability Criteria

The criteria-validation process examined whether the proposed environmental, economic, and social dimensions provided sufficiently complete and understandable coverage of sustainability concerns in public-sector information systems. Fourteen criteria were initially considered. Eight were retained without substantive modification, three were revised to improve their operational definitions, two overlapping criteria relating to hardware efficiency and computing-resource utilisation were merged into computing-resource optimisation, and organisational reputation was removed because stakeholders considered it an indirect outcome substantially overlapping with public trust. Stakeholder consultation also resulted in the addition of stakeholder participation as an explicit social criterion.

The final hierarchy therefore contained 13 criteria: four environmental, four economic, and five social criteria. The environmental dimension comprised energy efficiency, paper consumption reduction, carbon-footprint minimisation, and computing-resource optimisation. The economic dimension contained development cost, operational expenditure, maintenance efficiency, and long-term cost-effectiveness. The social dimension consisted of citizen accessibility, service transparency, digital inclusion, stakeholder participation, and public trust.

The findings of the validation process demonstrated that the three-dimensional sustainability framework captured the key sustainability concerns across the three cases. Participants identified

no sustainability dimension that stood on its own and required separate treatment. Most of the issues that could have been classified as technical sustainability, such as scalability, modularity, interoperability and technology obsolescence, were instead interpreted as threats to economic sustainability or resource efficiency or even to the sustainability of the provision of public services. Thus, for the current decision context, the three dimensions were adequate, if their criteria were formulated in a way that treated sustainability as a unified dimension and not as separate categories.

The first important conclusion from the revisions was the translation of general sustainability concepts to practical decision criteria that stakeholders could consistently apply. One example was the replacement of the general maintenance cost concept with maintenance efficiency. Participants were then able to consider a wider range of factors including modularity of code, ease of modification, staffing costs, defect resolution, and future adaptation, as opposed to simply the cost of maintenance. Similarly, the practical accessibility of citizens was determined to mean the actual use of digital public services rather than mere usability. These refinements improved the alignment between sustainability goals and the assessable requirements of the information system.

AHP Criteria Weights

AHP was used to evaluate the sustainability dimensions and criteria that were of greatest importance prior to evaluating the individual criteria. The weights of the sustainability dimensions were, respectively, 0.382 for social sustainability, 0.341 for economic sustainability, and 0.277 for environmental sustainability. The local and global criteria weights, overall ranking, the weights of the stakeholder groups, and the results of the evaluation of consistency can be found in Table 3.

Table 3. AHP Weights and Consistency Results for Sustainability Dimensions and Criteria

Dimension	Criterion	Local weight	Global weight	Overall rank	Technical stakeholder weight	Non-technical stakeholder weight	Consistency ratio
Environmental	Energy efficiency	0.340	0.094	3	0.109	0.082	0.052
Environmental	Paper consumption reduction	0.180	0.050	11	0.055	0.046	0.052
Environmental	Carbon-footprint minimization	0.160	0.044	13	0.053	0.035	0.052
Environmental	Computing-resource optimization	0.320	0.089	6	0.101	0.078	0.052
Economic	Development cost	0.180	0.061	10	0.058	0.064	0.061
Economic	Operational expenditure	0.250	0.085	7	0.082	0.088	0.061
Economic	Maintenance efficiency	0.310	0.106	1	0.123	0.091	0.061
Economic	Long-term cost-effectiveness	0.260	0.089	5	0.088	0.089	0.061
Social	Citizen accessibility	0.250	0.096	2	0.079	0.109	0.057
Social	Service transparency	0.200	0.076	8	0.067	0.084	0.057
Social	Digital inclusion	0.180	0.069	9	0.059	0.078	0.057
Social	Stakeholder participation	0.130	0.050	12	0.053	0.048	0.057
Social	Public trust	0.240	0.092	4	0.073	0.108	0.057

In total, social sustainability was the most comprehensively ranked dimension; however, the individual criterion of maintenance efficiency, weighing 0.106, was the highest rated globally. Citizen accessibility was the next highest rated criterion at 0.096, with energy efficiency weighing at 0.094

and public trust at 0.092. The lowest individual criterion weight was linked to the minimisation of carbon footprint at 0.044. The low ranking position of this criterion was not to indicate that the dimension of environmental impact was of little importance. The participants of the surveys commonly focused on actionable energy and computing resource efficiency criteria, as opposed to the broader carbon impact criteria that would be associated with an individual requirement of a software system.

Distinctions between stakeholder groups were evident too. For technical stakeholders, the highest weight was given to maintenance efficiency (0.123), energy efficiency (0.109) and computing-resource optimisation (0.101). The non-technical stakeholders gave the highest weight to Citizen accessibility (0.109), public trust (0.108), operational expenditure (0.088) and service transparency (0.084), which indicated that the technical stakeholders were concerned about the system's maintenance, while non-technical stakeholders were concerned with the service being accessible, accountable, affordable and legitimate.

All the compared aggregated matrices fulfilled the established consistency level. The consistency ratios were in the range 0.052 to 0.061 and were lower than 0.10. In the ranking process that followed, the consistent relative assessments were considered acceptable.

Fuzzy TOPSIS Ranking of Sustainability Requirements

To arrive at the final priorities of the 12 validated sustainability requirements using global AHP weights, the fuzzy decision matrix was employed. Linguistic assessments of the stakeholder groups were consolidated, normalised, and weighted. The distances in relation to the fuzzy positive and negative ideal solutions were then calculated. The closeness coefficients and the final ranking are displayed in Table 4.

Table 4. Fuzzy TOPSIS Ranking of Sustainability Requirements

Requirement ID	Sustainability requirement	Primary dimension	Distance to positive ideal	Distance to negative ideal	Closeness coefficient	Final rank	Priority category
R9	Maintainable modular system architecture	Economic	0.188	0.812	0.812	1	Critical
R1	Accessible multi-channel public-service interface	Social	0.202	0.798	0.798	2	Critical
R3	Transparent transaction status and auditable service trail	Social	0.219	0.781	0.781	3	Critical
R10	Life-cycle cost optimization and technology sustainability	Economic	0.236	0.764	0.764	4	Critical
R5	Energy-efficient processing and infrastructure utilization	Environmental	0.252	0.748	0.748	5	High
R2	Low-bandwidth and digitally inclusive service access	Social	0.274	0.726	0.726	6	High
R6	Optimized computing, storage, and network resources	Environmental	0.289	0.711	0.711	7	High
R11	Operational-cost monitoring and scalable resource allocation	Economic	0.316	0.684	0.684	8	High
R4	Trust-supporting privacy and service accountability controls	Social	0.343	0.657	0.657	9	Moderate
R7	Paperless workflow and electronic document processing	Environmental	0.368	0.632	0.632	10	Moderate

Requirement ID	Sustainability requirement	Primary dimension	Distance to positive ideal	Distance to negative ideal	Closeness coefficient	Final rank	Priority category
R12	Structured stakeholder feedback and participation mechanism	Social	0.414	0.586	0.586	11	Moderate
R8	Carbon-aware infrastructure and deployment practices	Environmental	0.479	0.521	0.521	12	Low

There were two common features of the highly ranked requirements. First, they exhibited effects across multiple sustainability dimensions. For example, the building of a maintainable modular architecture decreased the expected effort of maintenance while allowing adaptation and scalability and extending the life of the system. Second, they addressed broader recurrent operational issues rather than addressing discrete sustainability outcomes.

The requirement of carbon-aware infrastructure and deployment practices received the lowest ranking. While stakeholders appreciated the rationale, the perceived contribution of the requirement was less direct at the requirement level when compared to energy efficiency or resource minimisation. A similar case was observed for the ranking of the paperless workflow. This requirement was ranked as moderate instead of critical since its contribution varied with the case under consideration. In Case B, this requirement was highly pertinent, whereas in the financial and citizen service systems, this requirement was of less consequence.

3.5 Comparison Across Case-Study Systems

The prioritisation of the requirements clearly separated the three cases considered. In Case A, the highest ranked requirements were citizen accessibility, low bandwidth inclusive access, and tracking service with visibility. With a citizen-oriented system, stakeholders appreciated the sustainability of the digital transformation in the context of the transformation of the service from limiting access to government services to empowering and enabling access to government services.

Case B produced a unique ranking. Modular designs that allow for future changes and additions to the system were ranked first, followed by building a paperless workflow and optimising computing resources. The administration platform relied on the processing of a high volume of internal forms. As a result, the participants were more interested in eliminating redundant processing, controlling the growth of the stored data, simplifying future integrations, and automating administrative tasks that are currently conducted using paper.

With respect to Case C, the highest ranking was given to systems that provide transaction transparency and audit trails, followed by maintainable modular architecture, and optimisation of the total cost of ownership over the life cycle of the system. For financial management systems, stakeholders associated sustainability with the system's capability to maintain operational continuity and the assurability that no substantive changes to the operational process will be lost, in addition to operational responsibility and adjustment capabilities to the changing regulations of financial practice.

The rank correlations between the overall ranking and case-specific rankings were positive and relatively high in all three cases, with Spearman coefficients of 0.84 for Case A, 0.81 for Case B, and 0.86 for Case C. This indicates that context influenced the ordering of requirements without creating lots of competing sustainability models. The results support using a common sustainability hierarchy, but also show that requirements should not be prioritised in a mechanical way.

3.6 Technical and Non-Technical Stakeholder Perspectives

Stakeholder-group analysis showed systematic differences in the interpretation of sustainability. In the technical group, participants stressed reasons for maintaining an efficient system, the use of computing resources, the efficiency of energy consumption in system processing, the scalability of the system, and the modularity of the system. Their assessment reflected their direct accountability

for ensuring the performance of the system and the flexibility of the applications in adjusting to the demands of varying conditions.

In the non-technical group, managers and administrative participants also evaluated operational expenditure and cost, the reliability of service delivery, and the sustainability of the system. Citizen and user participants valued accessibility, digital inclusion, transparency, and the trust of the users. Evaluations of accessibility (mean importance score 4.71), transparency (mean importance score 4.63), and digital inclusion (mean importance score 4.58) were highest in this participant group.

These distinctions enable the negotiation of requirements as no single group of stakeholders captured the full scope of sustainability. A technical-dominated prioritisation process would have increased requests for maintainability and efficiency while perhaps neglecting the impact on citizens. Conversely, a non-technical-dominated process would neglect the impact on citizens and neglect the impact on the architecture of the social and economic benefits from sustainability. Therefore, the integrated framework has added value as not only a ranking methodology but also as a tool to make visible the differences in priorities for stakeholders before commitments to the project are made.

3.7 Sensitivity and Robustness Results

Stability of the ranking of requirements was analysed by changing the relative importance of the environmental, economic, and social dimensions. The baseline ranking was compared to an environment-dominant, cost-constrained, social-inclusive, and balanced sustainability, as demonstrated in Figure 3.

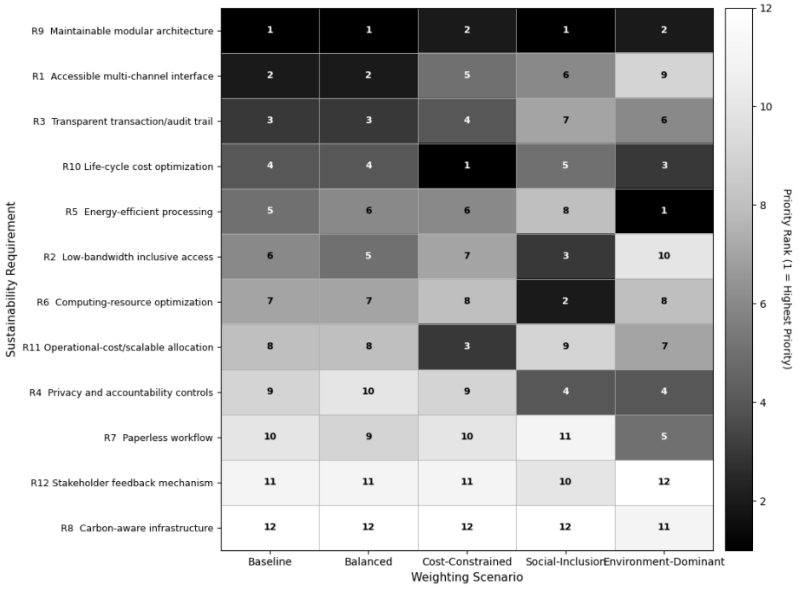


Figure 3. Rank Stability of Sustainability Requirements Across Weighting Scenarios

A ranking almost identical to the baseline was obtained in the balanced scenario with a correlation of 0.986. In the cost-constrained scenario, substantial similarity was obtained (ρ = 0.832). However, a high degree of reordering was observed in the social-inclusion scenario (ρ = 0.636). The environment-dominant scenario yielded the greatest dissimilarity (ρ = 0.490).

Maintainable modular architecture and accessible multi-channel service always ranked in the top five under all scenarios. Transparent transaction and audit trails ranked in the top five almost always except under the environment-dominant scenario, and in that case, it ranked sixth. Energy-efficient processing ranked in the top five almost always except under the baseline and social inclusion scenarios, in which it ranked at eighth and fifth respectively, and under the environment-dominant scenario, in which it ranked at first. Likewise, low-bandwidth and inclusive access ranked at sixth under the baseline and at third under social inclusion, and at tenth under environment dominance.

Additional ±10% systematic perturbations of the baseline dimension weights yielded a median Spearman correlation of 0.91 and retained at least four of the baseline top-five requirements in 80%

of the configurations tested. The results show that the preferred ranking remained stable under moderate changes, but under extreme changes the order of importance could legitimately change. Such behaviour should not be viewed as a weakness of the framework. Rather, such behaviour indicates that some requirements may hinge on policy and should be subject to negotiation among stakeholders.

Discussion:

The environmental results indicate that stakeholders distinguished between objectives that directly influence the behaviour of software and objectives that concern broader system-level outcomes. Energy-efficient processing and computing resource optimisation were prioritised over carbon-footprint minimisation. This outcome is likely because of the constraints of the teams working on the projects. Processing, storage, network traffic, and demand on servers and the infrastructure that supports the system could all be specified and measured.

As for systems within the public sector that run continuously and serve large audiences, small inefficiencies can become significant cost drivers when large volumes of transactions occur over a long time span. With that in mind, operational constraints need to focus on reducing unnecessary processing and database queries, storage growth, workload consolidation, resource-aware scheduling, and eliminating unnecessary data transfers. In Case B, electronic workflows were essential for replacing reliance on repeated movement of physical documents with sustainability and administrative efficiency.

The results show that operational constraints offer a practical way to address sustainability issues. It is important to emphasise that reducing carbon is an important consequence of achieving these constraints. However, greater attention has to be paid to intermediary goals that the development and operations teams can control.

Discussion of Economic Priorities

The case study indicated that, from a financial point of view, the goal should not be to lower the cost as much as possible. Rather, the focus should be on keeping the system financially sound and adaptable throughout its life span. The trade-off between high cost and low first cost was clear as stakeholders ranked efficiency of maintenance as the most important consideration, followed by design for low life-cycle cost of ownership and low operational cost.

This is particularly relevant to public sector information systems since they have to be functional for long periods of time, and new integrations, changing regulatory environments, changes to access and transaction volumes, and security, as well as technology refreshes, occur. A low-cost solution could potentially incur high maintenance costs, rigidity of vendor partnerships, inefficient use of resources, or a number of system redevelopment cycles.

Scalability and technology obsolescence should be considered concurrently with direct development and operating costs. Investments should directly improve public service delivery and provide cost reduction advantages in the future to ensure long-term public value and sustainability.

Discussion of Social Priorities

The dimension weight for social sustainability was the highest, recognising the unique role public sector information systems should provide. Public trust, accessibility, transparency, and digital inclusion were considered important, along with top-ranked requirements of accessible services and tracking of service transparency. Unlike most private sector systems, access to a public information system may change an individual's ability to obtain a license or other administrative documents, financial services, benefits, information, or other government services. Therefore, accessibility should not be treated as an optional feature. Low-bandwidth support, alternative access channels, usability, transparent service status, and inclusive interaction become sustainability requirements of the system, as they may disadvantage certain user groups.

The importance placed on transparency and trust demonstrates the government institutional role of information systems. Users must know whether a transaction has been received, processed, approved, rejected, or is currently pending. Transparency of service records and accountability of service decisions ensure administrative accountability and public trust of government services

Theoretical Implications:

This study broadens the scope of Green Requirements Engineering and shows how sustainability requirements can be evaluated in an integrated way using environmental, economic, and social dimensions. The results show that environmental issues remain important, but do not necessarily take precedence when making sustainability decisions in the public sector. A second significant theoretical advance is the treatment of sustainability dimensions as measurable prioritisation criteria, rather than as abstract concepts. The prioritisation criteria construct a link between sustainability and requirement-level decisions. Third, the differences that technical versus non-technical participants exhibited indicate that the consideration of stakeholder plurality is a fundamental aspect of sustainable requirements engineering, rather than merely a procedural consideration. Finally, the findings indicate that requiring certain sustainability requirements to be prioritised is a part of sustainable digital governance. Deciding how sustainability requirements are prioritised affects how sustainability goals are transformed into real public sector digital services.

Methodological Implications:

The integrated framework has several methodological advantages. Separating AHP-based criteria weighting from Fuzzy TOPSIS-based alternative ranking eliminates the need for a large number of pairwise comparisons, which would be necessary if all the criteria were compared using AHP. Fuzzy linguistic ratings allow stakeholders to express opinions without being overly precise. The process creates a traceable analytical chain from stakeholder judgment to criteria weight, requirement evaluation, ideal-solution distance, closeness coefficient, and final priority. Separate stakeholder group analyses make visible what could otherwise remain hidden in a consolidated ranking. Consistency ratio checking ensures quality of the weighting judgment. Sensitivity and robustness analyses show the importance of the particular policy context.

Practical Implications:

The framework can be easily incorporated into many phases of public sector system policy management. In the early stages of initiative management, organisations can use the sustainability dimensions to state clear environmental, economic, and social concerns, and then choose alternative solutions. In requirements analysis, the criteria hierarchy can be used to classify candidate criteria and assess possible multidimensional concerns. During procurement, weighted sustainability criteria can be used along with conventional criteria of price, functionality, security and technical compliance, to assess provider tenders. During project approval, requirement priorities and sensitivity results can be used to justify the budget and governance decisions. During system evaluation, the operational criteria and indicators can be used to evaluate whether the prioritised sustainability requirements have been achieved and if the intended results have been obtained. Evaluation of stakeholders further demonstrated practical applicability. Among the 61 workshop participants, transparency rated 4.48 (SD = 0.55), usefulness 4.44 (SD = 0.57), clarity 4.36 (SD = 0.58), perceived fairness 4.31 (SD = 0.61), implementation feasibility 4.09 (SD = 0.66), and ease of use 4.02 (SD = 0.69). These responses reflect a high level of acceptance. They also suggest that once the framework is implemented in organisations with fewer resources and less decision-analysis expertise, a greater effort will be required to address the framework's usability and implementation.

Limitations:

When drawing conclusions from the findings, several limitations must be considered. The framework was assessed across three separate Public Sector Information System contexts. While this provided useful variation, it should also be recognised that this does not represent all the possible Public Sector Information Systems. Additionally, the stakeholder concerns were impacted by the organisational policies and operational challenges, which are also likely to differ in different jurisdictions and between different institutional contexts and public expectations.

The technique requires participants who can appreciate information systems and understand the implications of the assessed requirements. Linguistic gauging also reduces the burden of numerical precision, but scoring is still subjective and assessing different fuzzy definitions may result in minor shifts in closeness coefficients and rank order. Regulations, infrastructure, architecture, and citizen

expectations will likely evolve throughout the life cycle of the system, thus requiring an iterative reconsideration of the priorities and weights.

Small representation of citizens compared to representation of technologists, managers, and administrators may have reduced the range of perspectives for the public users. The research assessed the prioritisation process as opposed to assessing the implementation of environmental, economic, and social concerns. For these reasons, the research suggests that the following needs should be prioritised. In addition, evaluation methods should prioritise energy consumption, physical and financial costs of maintenance, and assessment of performance and efficiency of service to the public.

The results indicate that the requirements of sustainability in public sector information systems cannot be adequately addressed through priority setting based on the environment, economy, or technology. The integrated AHP-Fuzzy TOPSIS methodology established comparability of stakeholder requirements, rank ordering of requirements, and articulated sensitivity across the public sector services in the three domains. The results of the study reinforce the necessity of the integration of long-standing technical solutions, economics, sustainability, and equity in the public domain.

CONCLUSION

This study introduces and assesses an integrated framework for making sustainability trade-offs in the context of public sector information systems. Thirteen criteria were validated in each of the dimensions of sustainability, including four in the environmental and economic dimension and five in the social dimension. In this order, the dimensions of social, economic, and environmental sustainability, and the efficiency of system maintenance, gained the highest weight overall. In terms of individual sustainability criteria within the system, maintenance efficiency was the highest weighted criterion. In accordance with the Fuzzy TOPSIS approach, the highest priority requirements include a sustainable modular system architecture, the provision of multiple channels of user-centred access to public services, a transparent service track with a trail of auditable transactions, and optimisation of the life-cycle cost of the system. Stakeholder comparisons suggest that participants with a technical background focused on the criteria of maintainability, energy efficiency, and resource optimisation, while participants without a technical background emphasised the criteria of accessibility, trust, service transparency, and affordability. Results of cross-case and sensitivity analysis indicate that the main priorities in the overall sustainability of the system were fairly stable despite moderate changes in the composition of stakeholders and weight given to sustainability dimensions, while there were clear differences in the overall sustainability priorities in the system based on more extreme changes in sustainability dimensions due to social or environmental focus. These results provide direct answers to the five research questions regarding criteria importance, weight, requirements, sustainability, and usability.

The study introduces a sustainability criteria hierarchy with a stepwise transformation of ambiguous sustainability goals into measurable ranking criteria. Methodologically, the study proposes an integrated AHP-Fuzzy TOPSIS methodology that treats the criteria weighting and alternative ranking processes as separate steps. It also considers the judgment uncertainty of stakeholders due to language limitations and supports consistency and sensitivity assessments. The proposed requirement ranking serves as the basis for classifying priorities as critical, high, moderate, and low. In terms of stakeholder plurality, the framework enables the comparison of both technical and non-technical perspectives, in contrast to numerous other frameworks that integrate stakeholder plurality, in which different perspectives are lost in a single aggregated decision. Thus, the study proposes both a stakeholder-sensitive decision-support framework and a planning and governance framework tailored to the public sector's information systems.

Practically, the framework assists public organisations in avoiding prioritisation decisions based on a combination of short-term considerations of cost, urgency, and technical feasibility. Rather, decision-makers can assess the extent to which requirements support the optimisation of environmental resources, the sustainability of the economy, and equitable outcomes of the public

services. This provides a more explicit basis for the negotiation of requirements, the evaluation of tenders, justification of budget requests, approval of projects, and assessment of the systems.

The study should be considered within the three case study systems and the stakeholder groups involved. More extensive research efforts could involve larger samples in the intergovernmental domain, longitudinal validations, and assessments of the sustainability outcomes achieved after implementation. In addition, the framework could be integrated into requirements management systems along with the assessment of regulatory compliance and automated decision support systems. Evaluating the framework within the context of various public sector challenges using BWM, VIKOR, PROMETHEE, and DEMATEL could provide a comparative assessment of the framework and demonstrate the adequacy and robustness of alternative decision models.

ACKNOWLEDGMENT

The authors would like to express their sincere gratitude to all participating public-sector organizations and stakeholders who contributed their time, insights, and professional expertise throughout this study. Special appreciation is extended to the technical and non-technical participants involved in the interviews, assessments, and validation workshops. Their valuable contributions and perspectives were essential in identifying, evaluating, and validating the sustainability criteria and requirements for public-sector information systems. The authors also acknowledge the support and cooperation of the relevant institutions that facilitated access to the research context and information necessary for conducting this study.

AUTHOR CONTRIBUTION STATEMENT

Conceptualization: Author 1 and Author 2; Methodology: Author 1 and Author 3; Investigation: Author 1, Author 2, and Author 3; Data curation: Author 4 and Author 5; Formal analysis: Author 1 and Author 3; Validation: Author 2 and Author 3; Visualization: Author 1; Writing—original draft: Author 1; Writing—review and editing: All Authors; Supervision: Author 3. All authors have read and approved the final manuscript.

REFFERENCES

Abatan, A., Adeyinka, M. A., Sodiya, E. O., Jacks, B. S., Ugwuanyi, E. D., Daraojimba, O. H., & Lottu, O. A. (2024). The role of IT in sustainable environmental management: A global perspective review. *International Journal of Science and Research Archive*, *11*(1), 1874–1886. https://doi.org/10.30574/ijsra.2024.11.1.0288

AlNuaimi, B. K., Singh, S. K., Ren, S., Budhwar, P., & Vorobyev, D. (2022). Mastering digital transformation: The nexus between leadership, agility, and digital strategy. *Journal of Business Research*, *145*, 636–648. https://doi.org/10.1016/j.jbusres.2022.03.038

Amend, J., Kaiser, J., Uhlig, L., Urbach, N., & Völter, F. (2021). What Do We Really Need? A Systematic Literature Review of the Requirements for Blockchain-Based E-government Services. In *Lecture notes in information systems and organisation* (hal. 398–412). Springer International Publishing. https://doi.org/10.1007/978-3-030-86790-4_27

Bambazek, P., Groher, I., & Seyff, N. (2023). Requirements engineering for sustainable software systems: a systematic mapping study. *Requirements Engineering*, *28*(3), 481–505. https://doi.org/10.1007/s00766-023-00402-1

Bautista-Puig, N., Lozano, R., & Barreiro-Gen, M. (2022). Developing a sustainability implementation framework: insights from academic research on tools, initiatives and approaches. *Environment Development and Sustainability*, *25*(10), 11011–11031. https://doi.org/10.1007/s10668-022-02516-y

Behl, A., Singh, R., Pereira, V., & Laker, B. (2023). Analysis of Industry 4.0 and circular economy enablers: A step towards resilient sustainable operations management. *CentAUR (University of*

Reading), *189*, 122363. https://doi.org/10.1016/j.techfore.2023.122363

Budd, J., Miller, B. S., Manning, E., Lampos, V., Zhuang, M., Edelstein, M., Rees, G., Emery, V. C., Stevens, M. M., Keegan, N., Short, M., Pillay, D., Manley, E., Cox, I. J., Heymann, D., Johnson, M., & McKendry, R. A. (2020). Digital technologies in the public-health response to COVID-19. *Nature Medicine*, *26*(8), 1183–1192. https://doi.org/10.1038/s41591-020-1011-4

Choudhary, A., De, A., Ahmed, K. H. H., & Shankar, R. (2021). An integrated fuzzy intuitionistic sustainability assessment framework for manufacturing supply chain: a study of UK based firms. *Annals of Operations Research*, *349*(2), 687–730. https://doi.org/10.1007/s10479-019-03452-3

Demi, S. (2020). Blockchain-oriented Requirements Engineering: A Framework. *Duo Research Archive (University of Oslo)*, 428–433. https://doi.org/10.1109/re48521.2020.00063

Djatmiko, G. H., Sinaga, O., & Pawirosumarto, S. (2025). Digital Transformation and Social Inclusion in Public Services: A Qualitative Analysis of E-Government Adoption for Marginalized Communities in Sustainable Governance. *Sustainability*, *17*(7), 2908. https://doi.org/10.3390/su17072908

Ferrari, A., Bacco, M., Gaber, K., Jedlitschka, A., Hess, S., Kaipainen, J., Koltsida, P., Toli, E., & Brunori, G. (2022). Drivers, barriers and impacts of digitalisation in rural areas from the viewpoint of experts. *Information and Software Technology*, *145*, 106816. https://doi.org/10.1016/j.infsof.2021.106816

Guizzardi, R. S. S., Amaral, G., Guizzardi, G., & Mylopoulos, J. (2023). An ontology-based approach to engineering ethicality requirements. *Software & Systems Modeling*, *22*(6), 1897–1923. https://doi.org/10.1007/s10270-023-01115-3

Habibullah, K. M., Gay, G., & Horkoff, J. (2023). Non-functional requirements for machine learning: understanding current use and challenges among practitioners. *Requirements Engineering*, *28*(2), 283–316. https://doi.org/10.1007/s00766-022-00395-3

Harvey, C. R., & Rabetti, D. (2024). International business and decentralized finance. *Journal of International Business Studies*, *55*(7), 840–863. https://doi.org/10.1057/s41267-024-00705-7

Humble, N., & Mozelius, P. (2023). Design science for small scale studies: Recommendations for undergraduates and junior researchers. *European Conference on Research Methodology for Business and Management Studies*, *22*(1), 87–92. https://doi.org/10.34190/ecrm.22.1.1702

Ikwuanusi, U. F., Onunka, O., Owoade, S., & Uzoka, A. C. (2024). Digital transformation in public sector services: Enhancing productivity and accountability through scalable software solutions. *International Journal of Applied Research in Social Sciences*, *6*(11), 2744–2774. https://doi.org/10.51594/ijarss.v6i11.1724

Janowski, T., Estévez, E., & Baguma, R. (2018). Platform governance for sustainable development: Reshaping citizen-administration relationships in the digital age. *Government Information Quarterly*, *35*(4). https://doi.org/10.1016/j.giq.2018.09.002

Kroll, J. A. (2021). Outlining Traceability: A Principle for Operationalizing Accountability in Computing Systems. In *arXiv (Cornell University)*. Cornell University. https://doi.org/10.1145/3442188.3445937

Kukreja, V. (2022). Hybrid fuzzy AHP–TOPSIS approach to prioritizing solutions for inverse reinforcement learning. *Complex & Intelligent Systems*, *9*(1), 493–513. https://doi.org/10.1007/s40747-022-00807-5

Lo, H.-W., Wang, L.-Y., Weng, A. K.-W., & Lin, S.-W. (2024). Assessing Supplier Disruption Risks Using a Modified Pythagorean Fuzzy SWARA–TOPSIS Approach. *Journal of Soft Computing and Decision Analytics*, *2*(1), 169–187. https://doi.org/10.31181/jscda21202440

Lubis, S., Purnomo, E. P., Lado, J. A., & Hung, C.-F. (2024). Electronic governance in advancing sustainable development goals through systematic literature review. *Discover Global Society*, *2*(1). https://doi.org/10.1007/s44282-024-00102-3

McGuire, S., Schultz, E., Ayoola, B., & Ralph, P. (2023). *Sustainability is Stratified: Toward a Better Theory of Sustainable Software Engineering*. 1996–2008. https://doi.org/10.1109/icse48619.2023.00169

Muciaccia, T., & Tedeschi, P. (2023). Future scenarios for the infrastructure digitalization: The road ahead. *Frontiers in the Internet of Things*, *2*. https://doi.org/10.3389/friot.2023.1140799

Nazim, M., Mohammad, C. W., & Sadiq, M. (2022). A comparison between fuzzy AHP and fuzzy TOPSIS methods to software requirements selection. *Alexandria Engineering Journal*, *61*(12), 10851–10870. https://doi.org/10.1016/j.aej.2022.04.005

Olawumi, T. O., & Chan, D. W. M. (2021). Cloud-based sustainability assessment (CSA) system for automating the sustainability decision-making process of built assets. *Expert Systems with Applications*, *188*, 116020. https://doi.org/10.1016/j.eswa.2021.116020

Pazienza, A., Baselli, G., Vinci, D. C., & Trussoni, M. V. (2024). A holistic approach to environmentally sustainable computing. *Innovations in Systems and Software Engineering*, *20*(3), 347–371. https://doi.org/10.1007/s11334-023-00548-9

Pishchulov, G., Trautrims, A., Chesney, T., Gold, S., & Schwab, L. (2019). The Voting Analytic Hierarchy Process revisited: A revised method with application to sustainable supplier selection. *Research Explorer (The University of Manchester)*, *211*, 166–179. https://doi.org/10.1016/j.ijpe.2019.01.025

Robati, M., Oldfield, P., Nezhad, A. A., Carmichael, D. G., & Kuru, A. (2021). Carbon value engineering: A framework for integrating embodied carbon and cost reduction strategies in building design. *UNSWorks (University of New South Wales, Sydney, Australia)*, *192*, 107620. https://doi.org/10.1016/j.buildenv.2021.107620

Rocha, C. M. M., Ospino, M. D., Ramos, I., & Jagdish, A. M. G. D. M. (2024). Enhancing Sustainable Mobility: Multi-Criteria Analysis for Electric Vehicle Integration and Policy Implementation. *International Journal of Energy Economics and Policy*, *14*(1), 205–218. https://doi.org/10.32479/ijeep.15021

Rojas, L., & Macías, J. A. (2019). Toward collisions produced in requirements rankings: A qualitative approach and experimental study. *Journal of Systems and Software*, *158*, 110417. https://doi.org/10.1016/j.jss.2019.110417

Shallcross, N. J., Parnell, G. S., Pohl, E., & Specking, E. (2021). Informing Program Management Decisions Using Quantitative Set-Based Design. *IEEE Transactions on Engineering Management*, *70*(9), 3213–3228. https://doi.org/10.1109/tem.2021.3078387

Sharma, S. K., Metri, B., Dwivedi, Y. K., & Rana, N. P. (2021). Challenges common service centers (CSCs) face in delivering e-government services in rural India. *Government Information Quarterly*, *38*(2), 101573. https://doi.org/10.1016/j.giq.2021.101573

Shokhjakhon, J., & Komila, A. (2025). Administrative and Legal Regulation of The Provision of Public Services in Electronic Form. *International Journal Of Law And Criminology*, *5*(5), 75–78. https://doi.org/10.37547/ijlc/volume05issue05-10

Sun, T. Q., & Medaglia, R. (2018). Mapping the challenges of Artificial Intelligence in the public sector: Evidence from public healthcare. *Government Information Quarterly*, *36*(2), 368–383. https://doi.org/10.1016/j.giq.2018.09.008

Svensson, R. B., & Torkar, R. (2023). Not all requirements prioritization criteria are equal at all times: A quantitative analysis. *Journal of Systems and Software*, *209*, 111909. https://doi.org/10.1016/j.jss.2023.111909

Trkman, P., & Černe, M. (2021). Humanising digital life: Reducing emissions while enhancing value-adding human processes. *International Journal of Information Management*, *63*, 102443. https://doi.org/10.1016/j.ijinfomgt.2021.102443

Upadhyay, A., Mukhuty, S., Kumar, V., & Kazançoğlu, Y. (2021). Blockchain technology and the circular economy: Implications for sustainability and social responsibility. *Journal of Cleaner Production*, *293*, 126130. https://doi.org/10.1016/j.jclepro.2021.126130

Venters, C. C., Capilla, R., Betz, S., Penzenstadler, B., Crick, T., Crouch, S., Nakagawa, E. Y., Becker, C., & Carrillo, C. (2017). Software sustainability: Research and practice from a software architecture viewpoint. *University of Huddersfield Repository (University of Huddersfield)*, *138*, 174–188. https://doi.org/10.1016/j.jss.2017.12.026

Wilonotomo, W., Ryanindityo, M., Aji, K. P., Wiraputra, A. R., Bawono, S. K., Nurkumalawati, I., Nugroho, T. W. A., & Mulyawan, B. (2025). Investigating the role of information technology system integration, user acceptance and information technology satisfaction and security on efficiency and accuracy of immigration documents processing. *International Journal of Data and Network Science*, *9*(3), 633–644. https://doi.org/10.5267/j.ijdns.2024.8.004

Wu, J., Guo, S., Huang, H., Liu, W., & Xiang, Y. (2018). Information and Communications Technologies for Sustainable Development Goals: State-of-the-Art, Needs and Perspectives. *IEEE Communications Surveys & Tutorials*, *20*(3), 2389–2406. https://doi.org/10.1109/comst.2018.2812301