

Article

Selecting Life Cycle Cost Indicators for Sustainable Public Procurement: A Fuzzy Delphi Consensus from Indonesia

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Abstract

Sustainable public procurement (SPP) has emerged as a crucial strategy for advancing environmental management and socioeconomic development. Life Cycle Cost (LCC) is widely regarded as a quantitative measure of long-term economic viability. However, integrating LCC analysis into SPP remains a major challenge. This study addresses this gap by identifying and selecting LCC indicators that align with sustainable procurement. This study develops new indicators for LCC assessment through a mixed-methods approach that combines a systematic literature review, an institutional policy review, and expert stakeholder consensus via a fuzzy Delphi method. A panel of 12 experts evaluated the indicators, and of the 173 potential items generated from the literature review, consensus was reached on 88 indicators, with an average threshold value (d) = 0.182. The findings establish a systematic framework that highlights the cost indicators most critical for guiding public procurement decisions. The findings also suggest indicators that are priorities for LCC in sustainable public procurement. Selecting appropriate LCC indicators in the SPP will help the government achieve several Sustainable Development Goals (SDGs) targets.

Keywords: sustainable public procurement; life cycle cost; sustainable development goals

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1. Introduction

Public procurement serves as a strategic policy instrument for governments to achieve societal objectives for sustainable goods and services [1,2]. This strategic role of procurement is underscored by its significant economic footprint, as public expenditure on goods and services accounts for approximately 14% of the European Union's Gross Domestic Product (GDP) [1,3]. In Indonesia, procurement spending ranges from 45–47% of the State Budget to approximately 6% of total GDP [4,5]. The vast government spending on public procurement is expected to contribute to the Sustainable Development Goals (SDGs).

Indonesia's pledge to achieve the SDGs is outlined in Presidential Regulation Number 111 of 2022 on the implementation of the achievement of sustainable development goals. The commitments are designed to address a range of global challenges, including poverty, inequality, climate change, environmental degradation, peace, and justice. Several government sectors have incorporated social and environmental responsibilities into their sustainable development policies. The Ministry of Environment and Forestry, for example, regulates green procurement for photocopy paper, lamps, and eco-friendly hotels. These regulations are applied within government agencies and promoted to the private sector, even though challenges to wider adoption remain [4]. This regulatory initiative illustrates how Indonesia's pursuit of the SDGs is linked to the broader conceptual evolution of sustainability.

The role of sustainability is also emphasized through government procurement regulation. Presidential Regulation Number 16 of 2018 on Government Procurement, as amended by Presidential Regulation Number 46 of 2025, mandates that government procurement of goods and services be carried out with consideration of sustainability aspects. This allows the government to implement procurement practices for goods and services that align with the SDG targets. Sustainability aspects in government procurement of goods and services include economic, environmental, and social factors. Economic aspects encompass the cost of producing goods and services throughout their life cycle; social aspects comprise empowering small businesses, ensuring fair working conditions, strengthening local communities, promoting equality, and fostering diversity; and environmental aspects entail reducing negative impacts on health, air quality, soil quality, and water quality, while ensuring the responsible use of natural resources in line with statutory provisions.

The implementation of government procurement policies for goods and services is increasingly reinforced by sustainable procurement guidelines (Decision of The Head of LKPP Number 157 of 2024 about Guidelines for Sustainable Public Procurement of goods/services). These guidelines specify the considerations that procurement actors within government institutions must address when applying sustainability principles in public procurement financed through the state budget. The guidelines also provide information on sustainable procurement arrangements and practices. They can be used by all parties involved in procurement to drive sustainable government procurement strategies, planning, and stages across all government agencies. However, despite the existence of these guidelines and the benefits of using sustainability principles, in practice, few government procurement tenders have applied sustainable principles. This is partly due to challenges in implementation [6].

The concept of sustainability has gained significant traction across industries and sectors, particularly within the public procurement domain [7–9]. Governments and public agencies can leverage their purchasing power to promote sustainability by embedding environmental, social, and economic considerations into procurement processes [10,11]. This growing interest has created a need for tools, methodologies, and frameworks to help public institutions evaluate and implement SPP. Among the diverse strategies available to advance sustainable public procurement, Life Cycle Cost (LCC) analysis stands out as particularly significant [3,10,12–13]. As both a theoretical framework and an operational mechanism, LCC enables public institutions to embed sustainability into procurement practices and align with the Sustainable Development Goals (SDGs).

LCC is a key tool in public procurement, assessing more than just the purchase price of goods and services. By considering costs across the product's life cycle—such as operation, maintenance, and disposal—LCC promotes more sustainable purchasing decisions [12]. It enables decision-makers to assess trade-offs between procurement options regarding economic, environmental, and social impacts [14]. As a result, LCC analysis embeds

sustainability in procurement by linking short-term costs with long-term effectiveness and ecological responsibility. This expanded cost logic directly supports the United Nations 2030 Agenda goal by operationalizing SDG 12 on accountable consumption and production through procurement practices that prioritize durability, resource efficiency, and minimizing total cost over the asset's lifetime. In the context of Indonesian public procurement—where public spending accounts for a significant share of national development financing—such a shift is fundamental, as conventional lowest-price evaluation methods have traditionally contributed to premature asset failure, high maintenance burdens, and suboptimal fiscal outcomes. From a theoretical standpoint, LCC functions as a bridge between SPP and intertemporal efficiency, in line with the principles of SDG 8 (decent work and economic growth) and SDG 9 (industry, innovation, and infrastructure). Empirical studies show that LCC-based procurement enhances value for money by revealing that greater upfront investments in quality, energy efficiency, and technological innovation frequently yield lower total public expenditure over the asset life cycle. This insight is highly relevant for Indonesia's infrastructure-intensive development agenda, where long-lived assets such as roads, public buildings, energy systems, and water infrastructure dominate procurement portfolios. By embedding LCC into evaluation criteria, public buyers can mitigate lifecycle risks associated with tropical climates, intensive use, and escalating energy costs—factors that are often underestimated in price-based tendering systems.

However, the success of LCC in SPP depends not only on selecting indicators that adequately capture environmental and economic impacts but also on ensuring that these indicators reflect broader socio-economic objectives [14,15]. Indicators must be relevant, measurable, and aligned with sustainability goals, yet their selection is inherently complex due to competing criteria such as ecological performance, social responsibility, and financial viability [15]. Importantly, socio-economic dimensions, such as labor, the empowerment of small or local communities/businesses, equality, and diversity, are a critical yet often underemphasized aspect of SPP [16,17]. Embedding these dimensions into LCC frameworks highlights how procurement decisions go beyond cost efficiency to encompass the empowerment of local communities, thereby linking technical evaluation with social policy objectives.

Thus, the relationship between SPP, as measured by LCC indicators, and socio-economic goals underscores a research gap: while environmental and economic criteria are well established [18], integrating socio-economic empowerment into LCC-based procurement remains underexplored. Therefore, the main question this study seeks to answer is: How can LCC in SPP be operationalized to balance sustainability objectives with socio-economic procurement policies? To answer this question, this study aims to integrate LCC indicators across all aspects of SPP in Indonesia.

The relevance of this research lies in its potential to significantly improve decision-making in public procurement by developing a framework for selecting LCC indicators. As public sector organizations increasingly prioritize sustainability [6,17], the ability to make informed and transparent decisions about public procurement practices becomes important [19], including the development of sustainable criteria [20]. This study addresses methodological gaps in applying LCC to SPP and offers practical insights for policymakers and procurement officials. By refining the process for selecting LCC indicators, the research contributes to the broader goal of embedding sustainability in public-sector decision-making and fostering a more sustainable global economy.

This study contributes to the literature by extending existing LCC frameworks (e.g., [3,13,14]) beyond environmental and economic dimensions, the paper explicitly incorporates socioeconomic empowerment, thereby operationalizing procurement as a tool for multidimensional public value creation. Methodologically, the paper advances indicator

selection by applying a fuzzy Delphi approach, ensuring rigor and replicability. These contributions position the study as both a theoretical and practical enhancement to sustainable public procurement research. The remainder of this paper is structured as follows: Section 2 reviews the relevant theoretical background. Section 3 outlines the methodology. Section 4 presents the results and discussion. Finally, Section 5 concludes with the findings and directions for future research.

2. Theoretical Background

2.1. Sustainable Public Procurement

Sustainable Public Procurement (SPP) is a systematic approach to identifying and encouraging the procurement of goods, works, and services that are assessed as less damaging to the environment during their production, use, and disposal than other goods or services serving the same purpose, while also considering economic, social, and institutional impacts [21,22]. SPP in the public sector involves acquiring goods, services, and works in a socially, economically, and environmentally responsible manner [22,23].

SPP has been studied extensively in many developed [6,22,24–29] and developing countries [7,29–30]. However, developing countries face more significant challenges [23]. Although SPP implementation has grown rapidly in many countries, it still faces several weaknesses, including limited economic efficiency, inadequate expertise and awareness among procurement personnel, unclear policies, and issues with organizational culture, management systems, and leadership perspectives [6]. In addition, the lack of incentives, senior support, and regulations hinders its effectiveness [24]. From different perspectives, the most significant challenges public procurement committees face is the lack of local production capabilities and inadequate infrastructure for purification and reuse [9].

The primary objective of SPP is to promote sustainable development [23]. The concept of Sustainable Public Procurement (SPP) has evolved from Green Public Procurement (GPP), and both approaches focus on the entire life cycle and emphasize environmental benefits [6]. GPP has a narrower scope than SPP and focuses on environmental aspects such as energy efficiency and green products [6]. In this study, we used sustainability as a term linking SPP, GPP, and circular public procurement (CPP) [9,31,32]. CPP emphasizes integrating circular economy principles to reduce waste and environmental impact. For this reason, sustainability in this paper encompasses environmental, social, and economic factors [9,13,21,22].

2.2. Life Cycle Cost in Public Procurement

Several researchers have explored LCC theory, instruments, and tools for public procurement [12,33,34]. For example, ref. [33] examines LCC as an instrument for advancing strategic public procurement, positioning LCC beyond conventional cost accounting as a long-term, value-oriented governance tool that improves economic efficiency and policy alignment in public procurement. They argue that although LCC calculation tools are available and can be simple, a tool is needed that is more visually representative and supports comparisons between estimated and actual values. Using organizational theory, [12] found that, under certain conditions, the environmental and economic dimensions of sustainability stimulate the internalization of LCC at the public level. Focusing on economic sustainability, Gaus et al. [34] investigate the integration of economic sustainability within public procurement decision-making through the lens of LCC information. By applying organizational theory to eight public-sector case studies, the authors demonstrate that the effectiveness of LCC information in supporting economic sustainability depends not only on its measurement but also, critically, on its distribution, interpretation, and fit with the informational needs of diverse buying-center actors. They suggest that improved infor-

mation processing can link LCC more directly to sustainable outcomes, positioning LCC as a promising instrument for enhancing long-term economic considerations in public procurement. Ref. [14] proposed an integrated sustainability indicator (including LCC) and provided an example of sustainability recommendation software. A Smart SPP LCC-CO₂ Tool was recommended to promote SPP projects [3,35]. Even though the research has been supported by various tools and frameworks, the costs studied still emphasize economic and environmental aspects, with social dimensions often treated as secondary or omitted altogether. This narrow focus limits the ability of LCC to fully capture the multi-dimensional value of procurement decisions. In terms of frequency of use, although the theory, framework, and tools are available, the LCC case in public procurement has been used very little in public procurement research and practice [12], even though several developed countries consistently apply it [10]. Some reasons for the lack of LCC application in public procurement include public institutions' limited awareness of the importance of sustainability [12]. The issue of data completeness and form is also a problem [10].

LCC constitutes a comprehensive analytical framework for systematically evaluating all costs incurred by an asset throughout its operational life span, including acquisition, operation, maintenance, and end-of-life stages [10]. While LCC shares conceptual similarities with Total Cost of Ownership (TCO), TCO primarily emphasizes direct economic expenditures, whereas LCC adopts a broader perspective by explicitly incorporating environmental and social costs [12]. This expanded scope positions LCC as a critical decision-support tool for SPP, enabling public buyers to move beyond short-term price considerations toward a holistic assessment of long-term value and sustainability impacts.

The extended scope is also based on public value theory [36], which emphasizes that public institutions must create multidimensional value beyond cost efficiency. In the context of public procurement, it advocates integrating LCC indicators with social and community-oriented criteria, thereby aligning procurement practices with broader societal goals. Ultimately, LCC enhances the strategic alignment of procurement practices with sustainability objectives, contributing to the operationalization of GPP and CPP principles within public sector decision-making. The relationship framework between public procurement and LCC/TCO in this study is shown in Figure 1.

2.3. The International and Country Regulation on SPP

International and national regulations provide the foundation for SPP and the integration of LCC. Within the European Union, Directive 2014/24 establishes the legal basis for SPP, and Article 68 explicitly requires that contract awards take LCC into account. Similarly, the Asian Development Bank's Guidance Note on Procurement promotes LCC as a means of embedding sustainability into procurement decisions. In Indonesia, Presidential Regulation No. 12/2021 outlines four key policies, prioritizing domestic goods and services, supporting micro and small enterprises, encouraging research and creative industries, and implementing sustainable procurement, demonstrating strong alignment with both economic and social objectives. This is complemented by Decision No. 157/2024 of the National Public Procurement Agency, which provides detailed arrangements for sustainable procurement practices. Sector-specific regulations further reinforce these principles, including the Ministry of Environment and Forestry Regulation No. 56/2015 and the Ministry of Health's guidelines on medical equipment management, as well as global references such as the WHO's medical device regulations and the European Commission's LCC tool for green procurement. Taken together, these frameworks reveal both convergences, particularly in recognizing LCC as a sustainability mechanism, and divergence, with the EU and ADB emphasizing broad policy integration, while Indonesia places stronger emphasis on domestic industry empowerment and healthcare-specific applications.

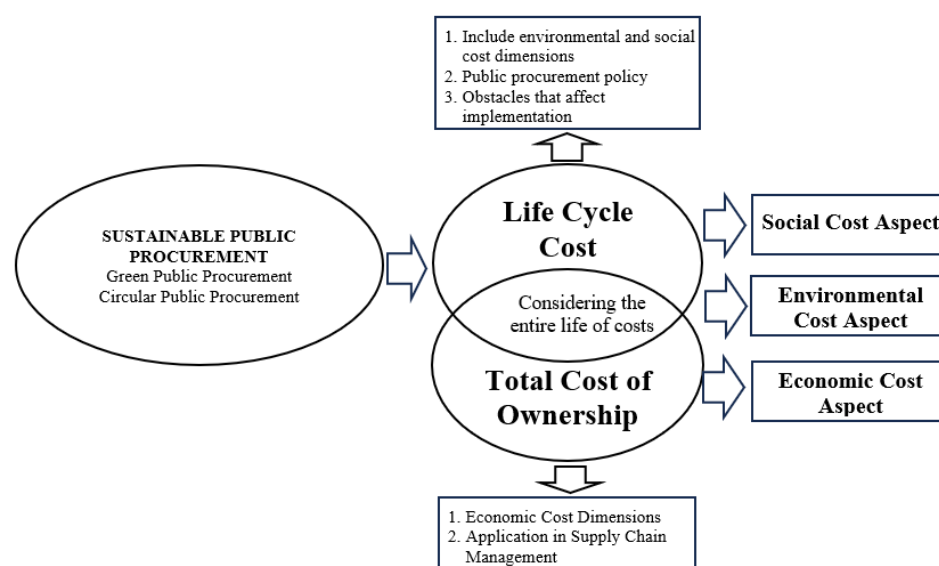


Figure 1. Public procurement relationship framework among SPP, GPP, CPP, LCC, and TCO (adapted from [12]).

2.4. Sustainability Indicator

To select sustainability indicators, researchers use several methods, including rigorous literature reviews [8,37,38] or surveys of experts [39,40]. One of the survey methods is the Delphi technique. For example, ref. [39] proposed 58 key factors influencing supplier selection, particularly when integrating environmental sustainability criteria. It identified key components of green supplier selection from the literature and then applied the fuzzy Delphi method. The method for selecting indicators through expert surveys also uses support vector machines [41] or principal component analysis [42]. The study by Ghosh et al. [42] aims to evaluate and select suppliers in this green supplier selection scheme, resulting in 13 criteria from the initial 25.

Using the practice-and-implementation approach of SPP, a relevant article by Neto [43] demonstrates the types of criteria that can be used in public procurement. Although there are ethical, social, and health criteria, environmental criteria dominate in public procurement schemes for food services (18 out of 28 criteria). Using text data mining of SPP implementation in Belgium, ref. [18] also identified seven main SPP categories and their subcategories. Environmentally friendly procurement is the most frequently implemented SPP category, followed by trade ethics and social return on investment. This approach, which does not rely on data from surveys or literature reviews, has the advantage of avoiding bias and low response rates.

3. Materials and Methods

This study presents a framework for identifying key indicators in sustainable public procurement. This research uses the Fuzzy Delphi Method (FDM). The FDM has emerged as a promising approach for identifying leading indicators of a construct. It combines the strengths of the traditional Delphi method, which builds consensus among experts, with fuzzy set theory, which accounts for vagueness and uncertainty in expert opinions [44,45]. The fuzzy aspect allows for the expression of imprecise judgments, making it particularly useful in situations where exact numerical inputs are difficult to obtain or not applicable [44]. By employing FDM, it is possible to establish a set of sustainability indicators that capture life-cycle costs, thereby improving the precision and reliability of SPP.

Therefore, this study is structured into three main steps. First, key indicators are identified through a comprehensive literature review and relevant regulatory frameworks. In

the second step, questionnaires are developed, and appropriate experts are selected to collect data. Finally, the collected data are analyzed using the FDM, a cost-effective approach that allows the use of a limited number of expert respondents while maintaining methodological efficiency and quality [45,46]. The methodological approach is summarized in Figure 2.

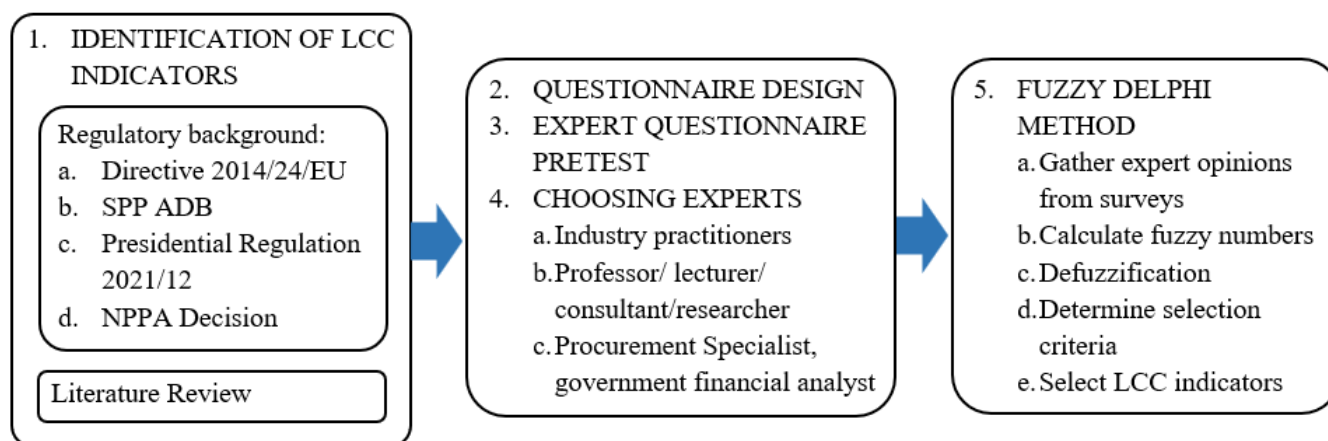


Figure 2. Methodological approach for selecting indicators (adapted from [45,46]).

3.1. Identification of LCC Indicators

This research is based on two scientific foundations to identify LCC indicators. First, international and national regulatory sources related to SPP cover economic, environmental, and social aspects. Second, a literature review of SPP in public projects related to LCC. The international and national regulatory indicators are taken from those discussed in Section 2.4.

We use a systematic literature review to select LCC indicators [47]. The selection process consists of several stages [48,49]. The first step is to search the literature using TITLE-ABS-KEY (title, abstract, and keywords). The title, abstract, and keywords included “total cost of ownership” or “life cycle cost,” combined with “sustainable public procurement,” “green public procurement,” or “circular public procurement” (including strings such as ‘cost*’ to include both cost and costing). We used Boolean “OR” and “AND” as search queries. This search was conducted in the Scopus collection, which was included in the topic search. Scopus was selected for its extensive coverage of peer-reviewed international journals and strong representation of research in procurement, sustainability, and public policy, thereby enhancing the comprehensiveness and reliability of the literature search. The search was conducted on 10 November 2024.

Using practical screening, 95 relevant studies were identified. After identifying the papers, articles were filtered using several criteria [48,49]. We limit our selection to English-language journals or conference proceedings. Publication years range from 2019 to 2024, reflecting the recency of the references, leaving 46 articles. The third stage is screening for accessibility, title, and abstract. However, the article must be readily accessible over the Internet. The last stage is full-text screening, which means the article discusses LCC for SPP (Figure 3). In addition to discussing LCC for SPP, this final criterion includes articles containing LCC elements and relevant case studies of LCC implementation. Because not all articles met these criteria, only 15 articles were accepted.

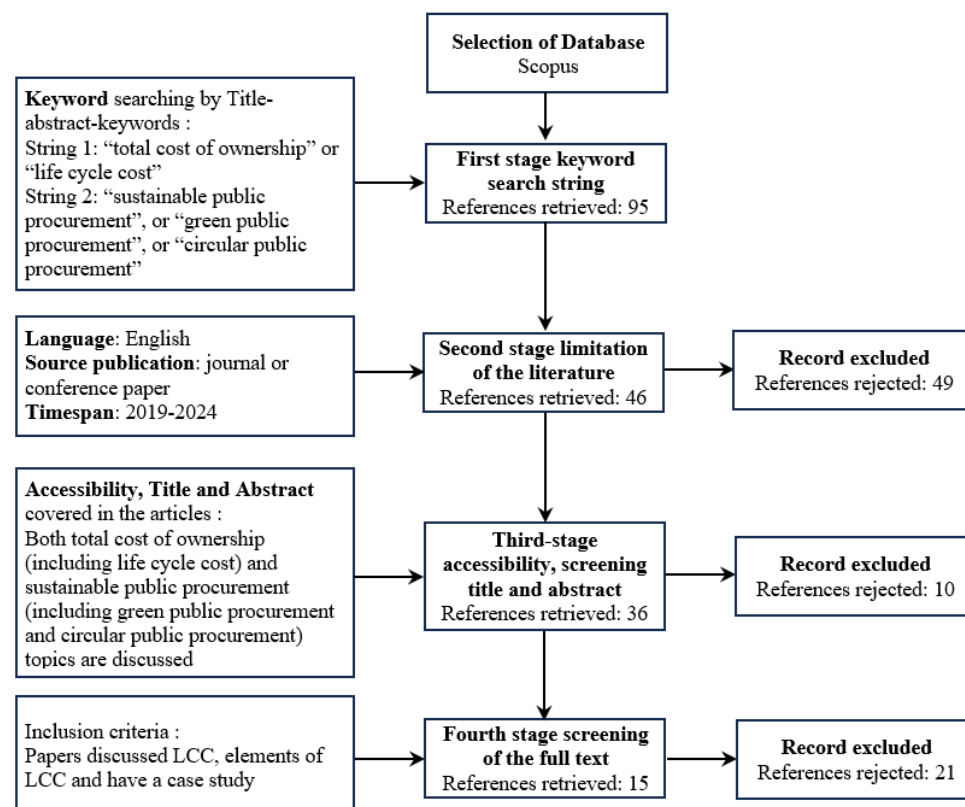


Figure 3. Literature review methodology (adapted from [48,49]).

3.2. The Questionnaire Design

The questionnaire is organized into two sections. Section 1 collects personal information, including name, age, education, field of expertise, and years of experience. Section 2 evaluates the significance and relevance of indicators across the economic, environmental, and social dimensions. Experts were asked to assess the importance of each indicator in the SPP context, using a fuzzy linguistic scale to express their judgments.

3.3. Expert Questionnaire Pretest

Pre-testing of the questionnaire was conducted with several experts to refine the clarity and relevance of the survey items. Meetings were held face-to-face, allowing participants to freely provide suggestions and opinions. The pre-test identified several issues, including ambiguous wording, overlapping items, and inadequate coverage of certain cost dimensions. Based on these findings, unclear questions were edited or removed, and additional items were introduced to capture potential cost indicators that had been overlooked in the initial draft. Although the pre-test was conducted with a small number of experts, these corrections improved the questionnaire's comprehensiveness and ensured the instrument was adequately validated.

3.4. Choosing an Expert and Data Collection

Following Wurster and Ladu [14], we identified three categories of respondents—companies, scientists, and procurement professionals. We contacted 31 potential respondents who fit these categories by searching government directories, academic publications, university expertise databases, industry collaborations, and personal networks. To mitigate selection bias in expert recruitment, respondents were purposively selected from three independent stakeholder groups—industry practitioners, academics, and government procurement professionals—thereby balancing practical, scientific, and policy per-

spectives and reducing the influence of any single institutional viewpoint. After identifying potential experts, we distributed the questionnaire via Google Forms and/or paper. Google Forms enabled faster data collection, while paper questionnaires, combined with face-to-face meetings, allowed respondents to suggest additional indicators. Ultimately, we received responses from twelve individuals, yielding a questionnaire return rate of 38%. The relatively low response rate was due to incomplete or invalid submissions. Table 1 describes the respondents.

Table 1. Characteristics of potential experts.

No.	Category	Description	Number of Respondents
1	Industry	Industry practitioners	4
2	Academic	Professor/lecturer/consultant	4
3	Government	Procurement specialist, government financial analyst	4
	Total		12

Industry experts include healthcare manufacturers and distributors in Indonesia. Academics are selected lecturers who understand LCC and/or have published international papers on LCC. Government representative respondents were drawn from national procurement agencies with experience in selecting suppliers. Table 2 provides a comprehensive overview of the key characteristics and attributes that define the experts, highlighting their primary features and distinguishing qualities.

Table 2. Characteristics and attributes of the experts.

Variables		Frequency	Percentage (%)
Organization	Industry practitioners	4	33
	Academic	4	33
	Government	4	33
	Total	12	100
Education	Doctor	2	17
	Master	5	42
	Bachelor	5	42
	Total	12	100
Experience in Procurement/LCC (years)	5–10	3	25
	11–15	3	25
	16 and more	6	50
	Total	12	100
Age (years)	30–39	4	33
	40–49	4	33
	50 and more	4	33
	Total	12	100

3.5. Fuzzy Delphi Method

The fuzzy Delphi method (FDM) analysis was used in the third step to establish expert agreement. To reduce ambiguity arising from experts' aptitude and subjectivity, this study uses seven Likert scales and triangular fuzzy numbers, as described in Table 3.

Table 3. Linguistic expressions and fuzzy Delphi numbers.

Linguistic Expression	Description	Likert Scale Scoring	Triangular Fuzzy Number		
			Lower Limit (L)	Middle Limit (L)	Upper Limit (L)
Extremely Unimportant	The indicator is not fundamental in SPP	1	0.00	0.00	0.10
Very Unimportant	The indicator is not very significant in SPP	2	0.00	0.10	0.30
Unimportant	The indicator is not important in SPP	3	0.10	0.30	0.50
Moderately Important	The indicator is slightly relevant in SPP	4	0.30	0.50	0.75
Important	The indicator is important in SPP	5	0.50	0.75	0.90
Very Important	The indicator is very significant in SPP	6	0.75	0.90	1.00
Extremely Important	The indicator is fundamental in SPP	7	0.90	1.00	1.00

Source: [44,50].

Consensus among experts using fuzzy number calculations is reflected in three requirements. The three value requirements for passing the selection are as follows:

- (1) The threshold value “d”

The first requirement is determined by the threshold value (d). This threshold indicates the distance between the fuzzy average numbers (x, y, z) and the Triangular fuzzy number (L, M, U). The first step is to convert the Likert scale value (from expert assessment) into a triangular fuzzy scale. Linguistic expressions are converted into Triangular fuzzy numbers. Triangular fuzzy numbers are represented by the symbols L, M, and U. The L value indicates the minimum value, the M value represents the middle value, and the U value represents the maximum value. Next, each fuzzy number’s average is calculated using the following formula [44]:

$$\text{Fuzzy average} = \left(\frac{\sum_{i=1}^n L_i}{n}, \frac{\sum_{i=1}^n M_i}{n}, \frac{\sum_{i=1}^n U_i}{n} \right), \quad (1)$$

where (n) is the number of experts. The threshold value (d) was then calculated using the following formula [44].

$$d = \sqrt{\frac{1}{3} [(x - L)^2 + (y - M)^2 + (z - U)^2]}, \quad (2)$$

Following refs. [51,52], the consensus threshold for triangular fuzzy numbers is set at $d \leq 0.2$, ensuring methodological consistency and replicability.

- (2) Percentage of experts’ agreement per item

The percentage of indicators meeting the first requirement (threshold value $(d) \leq 0.2$) must exceed 75% for each item or construct [44]. A 75% agreement among experts indicates agreement.

- (3) Determining the Crisp number

The third requirement for an item to be accepted is to use an α -Cut or a Crisp number [44]. The crisp number finds the maximum value of the Average Fuzzy Numbers called A1, A2, and A3, or of the Crisp numbers (Z^*).

$$Z^* = \max (A1, A2, A3), \quad (3)$$

These average Fuzzy Number formulas are applied as follows:

$$A_1 = \frac{x + y + z}{3}, \quad (4)$$

$$A_2 = \frac{x + 2y + z}{4}, \quad (5)$$

$$A_3 = \frac{x + 4y + z}{6}, \quad (6)$$

The alpha cut value is the midpoint between “0” and “1,” which is 0.5. Indicators with an alpha cut value below 0.5 indicate expert agreement to reject the indicator. Thus, if the alpha cut value is above 0.5, it indicates consensus in favor of accepting the indicator.

4. Results

Based on a previous literature review (15 relevant studies) and the regulatory background, the research sought potential indicators for LCC. We identified 173 potential indicators of LCC. As shown in Table 4, the indicators cover economic, environmental, and social aspects. Some indicators may not be critical, and certain aspects may be incomplete. Therefore, expert agreement and additional indicators are necessary.

Table 4. Summary of potential LCC indicators from literature and regulation.

Aspect	Dimension				Total
	Acquisition	Operation	Maintenance	End of Life	
Economic	22	21	10	11	64
Environmental	11	15	6	6	38
Social	14	19	19	19	71
Total	47	49	41	36	173

Some unique social indicators include forced labor, child labor, workers’ wages, equal opportunities, workers’ health and safety, end users’ health and safety, mechanisms for users to provide feedback, measures taken to address transparency, and fair market competition [14], energy security, sociotechnical system services, local/regional impact on land and aquatic environments [53], and external costs of pollution [54]. These indicators play a role across all product life cycles, from acquisition through end-of-life, so they are included in all dimensions.

After obtaining 173 indicators, the experts were asked to assess the importance of each indicator using FDM. As stated previously, a threshold value ($d \leq 0.2$) is applied to each defuzzification number to select the final indicators. The average value of d is 0.182, which is acceptable. The crisp value limit is 0.5. The FDM results are presented in Appendix A. The FDM process validated the list of LCC candidate indicators, resulting in the acceptance of 88 indicators (Figure 4). The distribution across dimensions was balanced: 25 indicators for acquisition, 36 for operations, 15 for maintenance, and 12 for end-of-life. This distribution demonstrates that the framework captures not only economic efficiency but also environmental sustainability and social empowerment.

To highlight the most critical indicators, Table 5 presents the top 10 items ranked by crisp value. Fuel cost and electricity were the highest-scoring indicators (0.930), followed closely by purchase cost, labor/staff cost, and waste management. These results confirm that operational costs dominate procurement decision-making, but the inclusion of indicators such as greenhouse gas emissions and labor costs underscores the multidimensional nature of sustainable public procurement.

Table 5. Top ten indicators with the highest Crisp value.

No.	Indicator	Dimension	Crisp Value
1.	Fuel cost	Operational	0.930
2.	Electricity	Operational	0.930
3.	Purchase cost	Acquisition	0.929
4.	Labor/staff cost	Operational	0.924

5.	Wastes	Operational	0.922
6.	Consumables	Operational	0.917
7.	Drinking water (supply, disposal)	Operational	0.917
8.	Personnel	Operational	0.917
9.	Investment cost	Acquisition	0.915
10.	Costs may include the cost of emissions of greenhouse gases	Operational	0.915

		DIMENSION			
		1. ACQUISITION	2. OPERATIONAL	3. MAINTENANCE	4. END-OF-LIFE
SUSTAINABILITY ASPECT	1. ECONOMIC	1.1.1 Purchase cost	2.1.1 Fuel cost	3.1.1 Maintenance cost	4.1.1 Resale/residual value
		1.1.2 Investment cost	2.1.2 Battery replacement cost	3.1.2 Repair	4.1.2 Recycling cost
		1.1.3 Post-acquisition cost items (distribution cost, management cost)	2.1.3 Labor/staff cost	3.1.3 Spare parts	4.1.3 Costs of disposal
		1.1.4 Manpower for the installation	2.1.4 Water consumption	3.1.4 Risk cost of shortage of spare parts	4.1.4 Costs of waste collection
		1.1.5 Rental of equipment	2.1.5 Consumables		4.1.5 Dismantling
		1.1.6 Installation cost	2.1.6 Electricity		4.1.6 Other disposal costs
		1.1.7 Construction price	2.1.7 Drinking water (supply, disposal)		4.1.7 Recycle material
		1.1.8 Material	2.1.8 Other operating supplies		4.1.8 Waste management of the used inhaler and the inhaler packaging
		1.1.9 Energy	2.1.9 Personnel (according to relevant pay groups)		4.1.9 Incineration
		1.1.10 Proportion of local content products	2.1.10 Fuel for heating		4.1.10 Energy recovery
	2. ENVIRONMENTAL	1.1.11 Technology transfer when purchasing the products	2.1.11 Financing cost		4.1.11 Landfilling
		1.1.12 Innovative products	2.1.12 Training costs		
			2.1.13 Equipment operation preparation cost		
			2.1.14 Proportion of local content consumables		
			2.1.15 Technology transfer products when human resource training		
		1.2.1 Environmental impact from raw materials	2.2.1 Environmental impact from raw materials	3.2.1 CO ₂ emissions	-
		1.2.2 Environmental impact from raw material transportation	2.2.2 Environmental impact from raw material transportation	3.2.2 Waste treatment costs	
		1.2.3 Environmental impact from waste processing	2.2.3 Environmental impact from waste processing	3.2.3 Environmental impact from deconstruction	
		1.2.4 Environmental impact from production	2.2.4 Environmental impact from the transportation of secondary materials	3.2.4 Total waste disposed	
		1.2.5 Environmental impact from transportation to the construction site	2.2.5 Environmental impact from production	3.2.5 Negative impact on human health	
	3. SOCIAL	1.2.6 Environmental impact of construction site	2.2.6 Wastes	3.2.6 Decline in air quality, soil quality, water quality	
		1.2.7 CO ₂ emissions	2.2.7 Emission to air		
		1.2.8 Non-hazardous waste	2.2.8 Emission to water		
		1.2.9 Hazardous waste	2.2.9 Noise		
		1.2.10 Environmental impact	2.2.10 Costs may include the cost of emissions of greenhouse gases		
			2.2.11 Other pollutant emissions		
			2.2.12 Climate change mitigation costs		
		1.3.1 Salary of workers	2.3.1 Health and safety of end users	3.3.1 Health and safety of workers	4.3.1 Social cost of carbon
		1.3.2 Health and safety of workers	2.3.2 Energy Security	3.3.2 Health and safety of end users	
		1.3.3 Guarantee of fair working conditions	2.3.3 Local/Regional Impact on Land and Aquatic Environments	3.3.3 Energy Security	
			2.3.4 Social cost of carbon	3.3.4 Local/Regional Impact on Land and Aquatic Environments	
			2.3.5 External cost of pollution	3.3.5 Social cost of carbon	
			2.3.6 Empowerment of small businesses		
			2.3.7 Guarantee of fair working conditions		
			2.3.8 Empowerment of local communities/businesses, Equality		
			2.3.9		

Figure 4. The final indicator for assessing LCC based on SPP.

5. Discussion

By life cycle phase, the findings reveal several critical insights. The highest Crisp value scores for the acquisition dimension were purchase cost (0.929) and investment cost (0.915). Experts conclude that the costs that must be included in the LCC calculation are these initial costs. Pre-acquisition cost items are part of another cost. Meanwhile, the proportion of local content products and the development of the local economy are characteristics of sustainable public procurement [8]. Although the “buy national products” policy contradicts the anti-discrimination principles of multilateral institutions such as the WTO [55], experts believe these costs are still necessary. Local content costs can take the form of cost-reduction subsidies for suppliers who provide goods with a certain level of domestic components. The use of domestic production is due to the government’s tendency to seek domestic products, even though foreign products are cheaper [56]. Many environmental indicators exist because of the importance of environmental considerations in public procurement. CO₂ emissions are one of the LCC costs that must be calculated [3].

The primary components of equipment operations, such as fuel (or energy), labor costs, consumables, and electricity, exhibit high Crisp values, averaging above 0.9, underscoring their importance. This finding is consistent with EU Directive [57] and other LCC studies [13,58]. The data reveals that experts highly value energy efficiency and manpower. The data also suggest that operational efficiency is a key concern for sustainable procurement, and that strategies to minimize costs while maintaining sustainability standards are essential. However, it is also noteworthy that environmental and local content costs are equally critical, reflecting their substantial relevance to the overall cost structure. Some unique costs, recognized by experts, include battery replacement. This compo-

nent can be generalized as the cost of an energy storage device. Its uniqueness lies in the fact that it is not necessarily present in all products. However, the lesson learned is that cheaper equipment with frequent energy storage device replacement may be more expensive in the long run than more expensive, durable options.

In the maintenance dimension, maintenance costs (0.899), including repair (0.876), spare parts (0.852), and the risk cost of spare parts shortages (0.810), are pivotal to the long-term sustainability of procured assets. Expert responses indicate strong consensus on the importance of these costs. Regarding maintenance contracts in LCC, ref. [59] propose three types of contracts: basic service, full service, and leasing. This maintenance contract option can help minimize the risk of future high maintenance costs, notably for complex products.

5.1. Rejected LCC Indicators

The many rejected indicators suggest that some are unimportant at each LCC level. These rejections indicate that the indicators do not yet meet the three requirements for consensus (see Section 3.5). The rejections may occur because experts lack agreement, possibly due to limited understanding and experience with LCC, both externally and internally within the organization [12]. However, rejection does not mean the indicators are irrelevant. It simply shows that, compared with other indicators, the interviewed experts ranked them as lower priority [45]. Alternatively, some rejected cost indicators may already be included in broader categories. For example, taxes and insurance—important costs for consumers, though not agreed upon—are part of broader costs, such as purchase or investment costs [3].

Indicators such as the risk cost of product shortages, communication cost, forced labor, and child labor did not pass selection because they had low Crisp values. However, indicators such as tax (0.831) [58], insurance (0.787) [14,58], procurement cost (0.774) [54], planning costs (0.786), transport cost (0.815), and equipment acceptance/commissioning cost (0.799) appear to need to be maintained. The reason for maintaining these indicators is that they have strong reasons and a Crispvalue exceeding 0.75.

In the operational dimension, indicators such as the cost of cleaning the product (0.807), replacement cost (0.833), cleaning cost (0.812), carbon emission cost (0.839), environmental impact from transportation to the construction site (0.753), environmental impact from construction (0.787), workers' salaries (0.802), equal opportunities (0.776), workers' health and safety (0.885), mechanisms for users to provide feedback (0.799), measures taken to address transparency (0.763), fair market competition (0.807), and diversity (0.782) are considered for retention because of their Crispvalue.

The lower acceptance of specific indicators (mainly the threshold value (d) for each Item, with the percentage of Items where $d \leq 0.2$), such as further follow-up costs, ordinary maintenance costs, and extraordinary maintenance costs, shows that the experts agree to reject them. Meanwhile, communication costs related to language and culture when maintaining and repairing the equipment, the proportion of local-content spare parts, and technology transfer when maintaining and repairing the equipment (0.768) show low expert agreement (the percentage of Items where $d \leq 0.2$ is less than 75%). Experts in this category cannot agree on the last social costs, suggesting that these are considered unpredictable or difficult to monetize in procurement models [10,57].

The end-of-life phase received comparatively less emphasis, with fewer accepted indicators. While resale value (0.857), recycling cost (0.847), and disposal costs (0.849) were considered relevant, environmental factors, such as CO₂ emissions, waste treatment costs, and environmental impacts from deconstruction, were deemed less critical. This may be due to the lack of standardized methodologies for calculating residual value in public procurement. For comparison, all end-of-life costs should be included in LCC unless the

manufacturer is responsible for financing the disposal process [60]. The relatively low frequency of social indicators used in the end-of-life phase reflects both methodological and theoretical challenges. Social costs, such as worker safety during deconstruction or community impacts of waste disposal, are difficult to quantify and often lack standardized measurement frameworks. This limitation suggests that current LCC practice underrepresents social sustainability at the disposal stage. Future methodological approaches could incorporate qualitative social impact assessments, standardized social LCC metrics, or sector-specific case studies to ensure that end-of-life decisions capture not only economic and environmental but also social dimensions of sustainability.

Although the indicators were selected from Scopus-indexed literature, several important studies on LCC and relevant SPP works could serve as sources due to their specific focus on social indicators. For instance, Knebel and Seele [28] identified 10 generic criteria to operationalize SPP in Switzerland, directly highlighting indicators such as gender pay gaps, anti-corruption measures, working conditions, human rights, and child labor. In contrast, ref. [8] examined social sustainability indicators relevant to defense and job creation in a different context, demonstrating varied applications of social criteria. Similarly, ref. [61] emphasized damage to consumers, local communities, and other value chain actors as a key social sustainability indicator, thereby broadening the perspective on the social dimension.

5.2. Empowering the Local Community

Several indicators related to empowering the local community significantly influence LCC. This is evident in the acceptance of indicators across both the acquisition and operational dimensions. In the acquisition dimension, examples include local-content products and technology transfer in product purchases. In the operational dimension, accepted indicators include local-content consumables and technology-transfer products used in human resource training. Experts agree that these indicators are an important part of the LCC. Furthermore, the only indicator for the empowerment of small businesses is found in the operational dimension of the social aspect. This indicates that small businesses are quite important and still need to be considered [18]. The acceptance of all those indicators reflects the Public Value perspective [36], in which procurement decisions are evaluated not only for financial efficiency but also for their capacity to generate socio-economic empowerment. Therefore, beyond the need for cost-effectiveness goals, all these indicators are a practical contribution to real socio-economic procurement that empowers local communities [62].

5.3. Implementation and Monetized Cost

To implement the selected indicators, procurement practitioners can integrate them into specific stages of the tender process [60]. For example, during prequalification, suppliers may be required to provide baseline data on equipment efficiency. Similarly, at the supplier bid evaluation stage, a weighted scoring approach can be used to balance financial costs with environmental and social performance throughout the life cycle. To ensure seamless integration of these indicators, practical implementation will involve (i) developing a mathematical model for the proposed indicators, (ii) examining interrelationships among the indicators, (iii) training procurement officers on their application, and (iv) piloting the approach on specific objects before full institutionalization.

However, the framework's international applicability requires careful consideration. In jurisdictions where procurement laws emphasize lowest-price criteria, implementing life cycle cost indicators may face regulatory or political resistance. Similarly, in developing countries, limited data availability and administrative capacity may hinder comprehensive implementation. To address these limitations, future adaptations could focus on

simplifying the indicator set for contexts with weak data infrastructure, while international organizations and donor agencies could support harmonization by providing capacity building and shared methodologies.

Both monetized and non-monetized indicators within LCC frameworks are essential for capturing the full spectrum of sustainability impacts. This advancement enables more informed decision-making aligned with the SDGs, ensuring that economic and non-economic factors are considered when evaluating products and processes. However, some non-monetized costs can be complex and challenging to measure [15,63], incomplete [55], subjective, and field-specific [64]. For this reason, care is needed when using these “externality” costs, including the involvement of competencies from various related sectors through a multidisciplinary approach [3].

6. SDG Target and Implication for Public Procurement Practice

The maintained LCC indicators are relevant to the Sustainable Development Goals (SDGs) and thus contribute to broader sustainability. For example, local content products, technology transfer, and the empowerment of small businesses support SDG 8 (Decent Work and Economic Growth); energy efficiency and waste reduction align with SDG 12 (Responsible Consumption and Production); transparency in maintenance costs strengthens SDG 16 (Peace, Justice, and Strong Institutions); and health and safety compliance advances SDG 3 (Good Health and Well-Being). These linkages underscore how the model integrates cost optimization with tangible contributions to global sustainability targets.

Based on the fuzzy Delphi results identifying priority LCC indicators, several important implications for public procurement practice emerge. First, this research demonstrates that public procurement authorities can operationalize sustainability objectives by embedding selected LCC indicators directly into tender evaluation criteria. This enables contracting authorities to move beyond selecting the lowest price toward a life-cycle-based value-for-money approach [57]. Second, the proposed LCC indicators provide a structured, transparent basis for evaluating the long-term economic consequences of procurement decisions, particularly the costs associated with operations, maintenance, and end-of-life stages. By making LCC cost indicators explicit, procurement evaluation committees can justify decisions that prioritize long-term efficiency and sustainability over short-term financial savings. Finally, including LCC indicators for local content, technology transfer, and small businesses supports procurement strategies that empower the local community. This approach allows public procurement authorities to recognize long-term socioeconomic benefits while maintaining compliance with public procurement principles of cost-effectiveness.

7. Conclusions

This study applied the FDM to evaluate LCC indicators in the context of SPP. The assessment drew on expert opinions and analyzed cost indicators across four key dimensions: acquisition, operational, maintenance, and end-of-life costs. The results provide a structured framework for understanding the cost indicators most relevant to decision-making in public procurement. Integrating FDM ensures that the findings are robust and reflect expert consensus. By highlighting key cost indicators and filtering out less significant ones, this research helps policymakers and procurement officers make informed decisions that balance cost-effectiveness with sustainability goals. From a policy perspective, the findings offer public procurement institutions a practical framework for integrating sustainability and local development objectives into procurement decision-making. The proposed LCC indicators support procurement reforms that emphasize long-term value

for money, transparency, and domestic economic development, thereby strengthening the role of public procurement as a strategic policy instrument.

From a theoretical perspective, this study contributes to the SPP literature by extending the use of LCC beyond a purely financial evaluation tool to a strategic mechanism for achieving broader sustainability objectives. The findings suggest that procurement decisions based on comprehensive LCC can better align economic efficiency with sustainability outcomes than traditional lowest-price approaches. Furthermore, the validated indicator framework provides a conceptual foundation for examining how cost considerations across the asset life cycle influence procurement decisions, supplier selection, and policy outcomes within SPP systems.

Building on these findings, future research may test several propositions: (P1) adopting LCC-based evaluation criteria in public procurement yields better sustainability performance than lowest-price procurement methods; (P2) procurement decisions that place greater weight on operational and maintenance costs result in lower total ownership costs over the asset life cycle; and (P3) integrating LCC indicators into tender evaluation enhances the participation and competitiveness of domestic suppliers by emphasizing long-term value rather than initial acquisition costs. Testing these propositions across sectors and national contexts would further strengthen the theoretical understanding of the relationship between LCC and sustainable public procurement outcomes.

While these results are relevant to public procurement, there are limitations. First, the variables were selected from a systematic literature review, which left the existing structure incomplete; thus, future research should expand the literature. Furthermore, the effectiveness of this method depends on local regulations and validation by a relatively small number of local experts with an Indonesian perspective ($n = 12$). Building on this, it is recommended that future research rely on international regulations and consult more regional experts to prevent bias from influencing the final results. Additionally, further studies could investigate the impact of LCC and practices on the procurement process, providing a more dynamic and up-to-date framework for SPP.

Importantly, the proposed framework has potential for transferability to other developing countries facing similar procurement challenges, offering a pathway to embed sustainability and socioeconomic empowerment into procurement systems globally. Future research should also focus on developing a mathematical model to weight the indicators and on piloting applications in specific sectors, such as healthcare and construction, thereby enhancing both methodological rigor and practical relevance.

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Appendix A

Table A1. Searching literature using Title-Abstract-Keyword Combined: (LCC or TCO) and (SPP or GPP or CPP).

Search Steps	Query	Number of Articles
Keyword searching by Title-abstract-keywords	(TITLE-ABS-KEY (life AND cycle AND cost*) OR TITLE-ABS-KEY (total AND cost AND of AND ownership)) AND (TITLE-ABS-KEY (sustainable AND public AND procurement) OR TITLE-ABS-KEY (green AND public AND procurement) OR TITLE-ABS-KEY (circular AND public AND procure-ment))	95
English language limits	(TITLE-ABS-KEY (life AND cycle AND cost*) OR TITLE-ABS-KEY (total AND cost AND of AND ownership)) AND (TITLE-ABS-KEY (sustainable AND public AND procurement) OR TITLE-ABS-KEY (green AND public AND procurement) OR TITLE-ABS-KEY (circular AND public AND procure-ment)) AND (LIMIT-TO (LANGUAGE, "English"))	92
Limits on journal or conference paper types	(TITLE-ABS-KEY (life AND cycle AND cost*) OR TITLE-ABS-KEY (total AND cost AND of AND ownership)) AND (TITLE-ABS-KEY (sustainable AND public AND procurement) OR TITLE-ABS-KEY (green AND public AND procurement) OR TITLE-ABS-KEY (circular AND public AND procure-ment)) AND (LIMIT-TO (LANGUAGE, "English")) AND (LIMIT-TO (SRCTYPE, "j") OR LIMIT-TO (SRCTYPE, "p"))	79
Limit year 2019–2024	(TITLE-ABS-KEY (life AND cycle AND cost*) OR TITLE-ABS-KEY (total AND cost AND of AND ownership)) AND (TITLE-ABS-KEY (sustainable AND public AND procurement) OR TITLE-ABS-KEY (green AND public AND procurement) OR TITLE-ABS-KEY (circular AND public AND procure-ment)) AND PUBYEAR > 2018 AND PUBYEAR < 2025 AND (LIMIT-TO (LANGUAGE, "English")) AND (LIMIT-TO (SRCTYPE, "j") OR LIMIT-TO (SRCTYPE, "p"))	46
Accessibility, Title and Abstract		36
Papers discussed LCC, elements of LCC and have a case study		15

Table A2. List of accepted and rejected LCC indicators.

No.	Indicators	Average of Fuzzy Number Lower Limit (L)	Middle Limit (M)	Upper Limit (U)	Threshold Value (d) per Item	Percentage of Each Item $d \leq 0.2$	Crisp Values (Z*)	Status
Acquisition								
1	Purchase cost	0.825	0.942	0.979	0.116	92%	0.929	Accepted
2	Tax	0.667	0.842	0.946	0.169	67%	0.831	Rejected
3	Insurance	0.621	0.792	0.921	0.220	58%	0.787	Rejected

4	Investment cost	0.788	0.925	1.000	0.050	100%	0.915	Accepted
5	Pre-acquisition cost items	0.554	0.738	0.871	0.270	25%	0.730	Rejected
6	Post-acquisition cost items	0.663	0.838	0.954	0.144	83%	0.828	Accepted
7	Manpower for the installation	0.675	0.858	0.950	0.157	100%	0.843	Accepted
8	Rental of equipment	0.663	0.850	0.950	0.147	75%	0.835	Accepted
9	Installation cost	0.713	0.871	0.954	0.173	92%	0.859	Accepted
10	Construction price	0.771	0.917	0.983	0.099	83%	0.903	Accepted
11	Material	0.738	0.896	0.975	0.112	75%	0.883	Accepted
12	Energy	0.750	0.904	0.975	0.119	75%	0.890	Accepted
13	Procurement cost	0.600	0.779	0.913	0.215	58%	0.774	Rejected
14	Additional infrastructure cost	0.575	0.775	0.908	0.166	67%	0.765	Rejected
15	Planning costs	0.608	0.796	0.917	0.192	58%	0.786	Rejected
16	Transport cost	0.654	0.825	0.925	0.219	42%	0.815	Rejected
17	Equipment acceptance/commissioning cost	0.629	0.808	0.925	0.199	58%	0.799	Rejected
18	Risk cost of product shortage	0.508	0.696	0.850	0.266	25%	0.693	Rejected
19	Communication cost in language and culture factor when purchasing	0.333	0.517	0.700	0.312	33%	0.521	Rejected
20	Proportion of local content products	0.738	0.896	0.975	0.112	75%	0.883	Accepted
21	Technology transfer when purchasing the products	0.700	0.863	0.954	0.166	92%	0.851	Accepted
22	Innovative products	0.654	0.833	0.946	0.160	75%	0.823	Accepted
23	Environmental impact from raw materials	0.704	0.875	0.967	0.125	100%	0.862	Accepted
24	Environmental impact from raw material transportation	0.633	0.821	0.938	0.162	75%	0.810	Accepted
25	Environmental impact from waste processing	0.746	0.900	0.983	0.081	83%	0.888	Accepted
26	Environmental impact from the transportation of secondary materials	0.579	0.767	0.904	0.203	58%	0.760	Rejected
27	Environmental impact from production	0.717	0.871	0.971	0.115	92%	0.863	Accepted
28	Environmental impact from transportation to the construction site	0.633	0.821	0.938	0.162	75%	0.810	Accepted
29	Environmental impact of construction	0.717	0.871	0.971	0.115	92%	0.863	Accepted
30	CO ₂ emissions	0.742	0.888	0.971	0.126	83%	0.878	Accepted
31	Non-hazardous waste	0.625	0.808	0.925	0.184	83%	0.797	Accepted
32	Hazardous waste	0.779	0.921	0.992	0.073	92%	0.909	Accepted
33	Environmental impact	0.663	0.838	0.954	0.144	83%	0.828	Accepted
34	Forced labor	0.429	0.579	0.738	0.376	42%	0.587	Rejected
35	Child labor	0.408	0.567	0.729	0.356	42%	0.574	Rejected
36	Salary of workers	0.725	0.888	0.975	0.105	75%	0.875	Accepted
37	Equal opportunities	0.625	0.817	0.929	0.170	67%	0.804	Rejected
38	Health and safety of workers	0.750	0.904	0.975	0.119	75%	0.890	Accepted
39	Health and safety of end users	0.729	0.892	0.967	0.140	67%	0.877	Rejected

40	Mechanisms for users to provide feedback	0.629	0.808	0.925	0.199	58%	0.799	Rejected
41	Measures taken to address transparency	0.596	0.767	0.900	0.251	42%	0.763	Rejected
42	Fair market competition	0.729	0.892	0.967	0.140	67%	0.877	Rejected
43	Empowerment of small businesses	0.671	0.825	0.925	0.213	75%	0.817	Rejected
44	Guarantee of fair working conditions	0.696	0.871	0.958	0.148	100%	0.856	Accepted
45	Empowerment of local communities/businesses,	0.683	0.833	0.925	0.219	67%	0.825	Rejected
46	Equality	0.633	0.800	0.921	0.229	50%	0.794	Rejected
47	Diversity	0.600	0.779	0.913	0.215	58%	0.774	Rejected
Operational								
48	Fuel cost	0.813	0.942	1.000	0.064	100%	0.930	Accepted
49	Battery replacement cost	0.688	0.854	0.954	0.159	92%	0.844	Accepted
50	Labor/staff cost	0.804	0.938	0.992	0.085	92%	0.924	Accepted
51	Diesel Bus Implementation Cost	0.458	0.633	0.804	0.302	58%	0.638	Rejected
52	Water consumption	0.729	0.879	0.971	0.120	92%	0.870	Accepted
53	Consumables	0.792	0.929	0.992	0.081	92%	0.917	Accepted
54	Cost of cleaning the product	0.642	0.817	0.925	0.209	50%	0.807	Rejected
55	Replacement cost	0.671	0.846	0.938	0.193	50%	0.833	Rejected
56	Electricity	0.813	0.942	1.000	0.064	100%	0.930	Accepted
57	Drinking water (supply, disposal)	0.792	0.929	0.992	0.081	92%	0.917	Accepted
58	Rainwater/service water	0.475	0.679	0.833	0.259	42%	0.672	Rejected
59	Other operating supplies	0.633	0.821	0.938	0.162	75%	0.810	Accepted
60	Personnel	0.792	0.929	0.992	0.081	92%	0.917	Accepted
61	Fuel for heating	0.663	0.838	0.954	0.144	83%	0.828	Accepted
62	Financing cost	0.692	0.867	0.967	0.117	100%	0.854	Accepted
63	Training costs	0.650	0.842	0.950	0.137	83%	0.828	Accepted
64	Equipment operation preparation cost	0.621	0.825	0.933	0.144	75%	0.809	Accepted
65	Tidying/cleaning cost	0.638	0.825	0.929	0.182	58%	0.812	Rejected
66	Communication cost in language and culture factor when operating	0.400	0.600	0.783	0.275	67%	0.601	Rejected
67	Proportion of local content consumables	0.696	0.871	0.958	0.148	100%	0.856	Accepted
68	Technology transfer products when human resource training	0.721	0.875	0.963	0.148	92%	0.865	Accepted
69	Carbon Emission	0.692	0.846	0.950	0.180	58%	0.839	Rejected
70	Environmental impact from raw materials	0.696	0.858	0.963	0.136	92%	0.849	Accepted
71	Environmental impact from raw material transportation	0.663	0.838	0.954	0.144	83%	0.828	Accepted
72	Environmental impact from waste processing	0.721	0.883	0.983	0.069	83%	0.873	Accepted
73	Environmental impact from the transportation of secondary materials	0.600	0.800	0.929	0.146	83%	0.789	Accepted

74	Environmental impact from production	0.700	0.850	0.958	0.158	83%	0.844	Accepted
75	Environmental impact from transportation to the construction site	0.567	0.763	0.896	0.195	42%	0.753	Rejected
76	Environmental impact of construction	0.621	0.796	0.913	0.223	67%	0.787	Rejected
77	Wastes	0.800	0.933	1.000	0.059	100%	0.922	Accepted
78	Emission to air	0.767	0.913	0.992	0.061	92%	0.901	Accepted
79	Emission to water	0.767	0.913	0.992	0.061	92%	0.901	Accepted
80	Noise	0.638	0.833	0.950	0.126	92%	0.820	Accepted
81	Costs may include the cost of emissions of greenhouse gases	0.788	0.925	1.000	0.050	100%	0.915	Accepted
82	Other pollutant emissions	0.758	0.908	0.983	0.090	83%	0.896	Accepted
83	Climate change mitigation costs	0.758	0.892	0.958	0.150	92%	0.881	Accepted
84	Forced labor	0.408	0.563	0.713	0.418	25%	0.567	Rejected
85	Child labor	0.429	0.588	0.754	0.357	42%	0.595	Rejected
86	Salary of workers	0.646	0.813	0.913	0.240	50%	0.802	Rejected
87	Equal opportunities	0.617	0.783	0.900	0.262	50%	0.776	Rejected
88	Health and safety of workers	0.742	0.900	0.967	0.147	67%	0.885	Rejected
89	Health and safety of end users	0.788	0.917	0.979	0.114	92%	0.906	Accepted
90	Mechanisms for users to provide feedback	0.629	0.808	0.925	0.199	58%	0.799	Rejected
91	Measures taken to address transparency	0.596	0.767	0.900	0.251	42%	0.763	Rejected
92	Fair market competition	0.642	0.821	0.917	0.211	58%	0.807	Rejected
93	Energy Security	0.750	0.892	0.979	0.094	92%	0.883	Accepted
94	Sociotechnical System Services	0.563	0.746	0.892	0.227	25%	0.742	Rejected
95	Local/Regional Impact on Land and Aquatic Environments	0.642	0.825	0.946	0.151	83%	0.815	Accepted
96	The social cost of carbon	0.596	0.808	0.933	0.116	92%	0.794	Accepted
97	The external cost of pollution	0.650	0.842	0.950	0.137	83%	0.828	Accepted
98	Empowerment of small businesses	0.779	0.921	0.992	0.073	92%	0.909	Accepted
99	Guarantee of fair working conditions	0.704	0.875	0.967	0.125	100%	0.862	Accepted
100	Empowerment of local communities/businesses,	0.779	0.921	0.992	0.073	92%	0.909	Accepted
101	Equality	0.717	0.883	0.967	0.133	100%	0.869	Accepted
102	Diversity	0.617	0.800	0.925	0.188	67%	0.792	Rejected
Maintenance								
103	Maintenance cost	0.775	0.908	0.979	0.108	92%	0.899	Accepted
104	Repair	0.738	0.883	0.979	0.089	92%	0.876	Accepted
105	Spare parts	0.713	0.858	0.958	0.162	83%	0.852	Accepted
106	Further follow-up costs	0.567	0.738	0.888	0.267	8%	0.738	Rejected
107	Ordinary maintenance costs	0.600	0.779	0.913	0.215	58%	0.774	Rejected
108	Extraordinary maintenance costs	0.629	0.808	0.925	0.199	58%	0.799	Rejected

109	Risk cost of shortage of spare parts	0.646	0.817	0.942	0.178	75%	0.810	Accepted
110	Communication cost in language and culture factor when maintenance and repairing the equipment	0.429	0.613	0.771	0.342	50%	0.612	Rejected
111	Proportion of local content spare parts	0.692	0.846	0.950	0.180	58%	0.839	Rejected
112	Technology transfer when maintenance and repair of the equipment	0.633	0.804	0.913	0.231	58%	0.794	Rejected
113	CO ₂ emissions	0.754	0.904	0.992	0.048	92%	0.894	Accepted
114	Waste treatment costs	0.738	0.883	0.979	0.089	92%	0.876	Accepted
115	Environmental impact from deconstruction	0.658	0.829	0.933	0.188	75%	0.818	Accepted
116	Total waste disposed	0.742	0.888	0.971	0.126	83%	0.878	Accepted
117	Negative impact on human health	0.763	0.900	0.979	0.100	92%	0.891	Accepted
118	The decline in air quality, soil quality, water quality	0.746	0.883	0.958	0.146	92%	0.873	Accepted
119	Forced labor	0.492	0.658	0.792	0.366	50%	0.657	Rejected
120	Child labor	0.446	0.608	0.767	0.366	50%	0.613	Rejected
121	Salary of workers	0.650	0.821	0.933	0.199	58%	0.813	Rejected
122	Equal opportunities	0.642	0.821	0.917	0.211	58%	0.807	Rejected
123	Health and safety of workers	0.713	0.863	0.950	0.165	92%	0.852	Accepted
124	Health and safety of end users	0.729	0.879	0.971	0.120	92%	0.870	Accepted
125	Mechanisms for users to provide feedback	0.629	0.808	0.925	0.199	58%	0.799	Rejected
126	Measures taken to address transparency	0.629	0.808	0.925	0.199	58%	0.799	Rejected
127	Fair market competition	0.646	0.813	0.913	0.240	50%	0.802	Rejected
128	Energy Security	0.688	0.854	0.954	0.159	92%	0.844	Accepted
129	Sociotechnical System Services	0.583	0.758	0.900	0.241	50%	0.756	Rejected
130	Local/Regional Impact on Land and Aquatic Environments	0.600	0.800	0.929	0.146	83%	0.789	Accepted
131	The social cost of carbon	0.600	0.800	0.929	0.146	83%	0.789	Accepted
132	The external cost of pollution	0.617	0.800	0.925	0.188	67%	0.792	Rejected
133	Empowerment of small businesses	0.679	0.850	0.946	0.178	58%	0.838	Rejected
134	Guarantee of fair working conditions	0.679	0.850	0.946	0.178	58%	0.838	Rejected
135	Empowerment of local communities/businesses,	0.663	0.833	0.925	0.210	58%	0.820	Rejected
136	Equality	0.633	0.804	0.913	0.231	58%	0.794	Rejected
137	Diversity	0.600	0.763	0.888	0.291	42%	0.758	Rejected
End-of-life								
138	Resale/residual value	0.708	0.867	0.963	0.142	92%	0.857	Accepted
139	Recycling cost	0.679	0.858	0.967	0.110	100%	0.847	Accepted
140	Costs of disposal	0.683	0.863	0.958	0.139	100%	0.849	Accepted
141	Costs of waste collection	0.650	0.842	0.950	0.137	83%	0.828	Accepted

142	Dismantling	0.650	0.842	0.950	0.137	83%	0.828	Accepted
143	Other disposal costs	0.600	0.800	0.929	0.146	83%	0.789	Accepted
144	Recycle material	0.650	0.842	0.950	0.137	83%	0.828	Accepted
145	Waste management of the used inhaler and the inhaler packaging	0.583	0.779	0.917	0.168	75%	0.771	Accepted
146	Incineration	0.633	0.821	0.938	0.162	75%	0.810	Accepted
147	Energy recovery	0.650	0.842	0.950	0.137	83%	0.828	Accepted
148	Landfilling	0.563	0.771	0.900	0.156	83%	0.758	Accepted
149	CO ₂ emission	0.633	0.804	0.913	0.231	58%	0.794	Rejected
150	Waste treatment costs	0.667	0.825	0.921	0.236	50%	0.815	Rejected
151	Environmental impact from deconstruction	0.633	0.804	0.913	0.231	58%	0.794	Rejected
152	Total waste disposed	0.679	0.833	0.921	0.243	42%	0.823	Rejected
153	Negative impact on human health	0.679	0.833	0.921	0.243	42%	0.823	Rejected
154	The decline in air quality, soil quality, water quality	0.646	0.792	0.896	0.310	25%	0.787	Rejected
155	Forced labor	0.338	0.508	0.683	0.350	33%	0.515	Rejected
156	Child labor	0.354	0.525	0.704	0.323	42%	0.533	Rejected
157	Salary of workers	0.596	0.771	0.892	0.254	50%	0.763	Rejected
158	Equal opportunities	0.563	0.729	0.867	0.306	8%	0.727	Rejected
159	Health and safety of workers	0.642	0.817	0.925	0.209	50%	0.807	Rejected
160	Health and safety of end users	0.663	0.829	0.933	0.207	50%	0.820	Rejected
161	Mechanisms for users to provide feedback	0.592	0.754	0.888	0.286	8%	0.753	Rejected
162	Measures taken to address transparency	0.546	0.708	0.854	0.327	0%	0.709	Rejected
163	Fair market competition	0.596	0.750	0.875	0.327	0%	0.748	Rejected
164	Energy Security	0.617	0.783	0.900	0.262	50%	0.776	Rejected
165	Sociotechnical System Services	0.546	0.725	0.879	0.252	17%	0.724	Rejected
166	Local/Regional Impact on Land and Aquatic Environments	0.638	0.813	0.933	0.190	67%	0.805	Rejected
167	The social cost of carbon	0.625	0.804	0.933	0.181	75%	0.797	Accepted
168	The external cost of pollution	0.567	0.758	0.904	0.192	33%	0.753	Rejected
169	Empowerment of small businesses	0.596	0.771	0.892	0.254	50%	0.763	Rejected
170	Guarantee of fair working conditions	0.617	0.783	0.900	0.262	50%	0.776	Rejected
171	Empowerment of local communities/businesses	0.617	0.783	0.900	0.262	50%	0.776	Rejected
172	Equality	0.629	0.792	0.900	0.270	42%	0.784	Rejected
173	Diversity	0.550	0.721	0.867	0.297	8%	0.719	Rejected

References

1. Grandia, J.; Meehan, J. Public Procurement as a Policy Tool: Using Procurement to Reach Desired Outcomes in Society. *Int. J. Public Sect. Manag.* **2017**, *30*, 302–309. <https://doi.org/10.1108/IJPSM-03-2017-0066>.
2. World Bank Procurement for Development. Available online: <https://www.worldbank.org/en/topic/procurement-for-development> (accessed on 10 May 2025).
3. Fregonara, E.; Ferrando, D.G.; Tulliani, J.M. Sustainable Public Procurement in the Building Construction Sector. *Sustainability* **2022**, *14*, 11616. <https://doi.org/10.3390/su141811616>.
4. Erizaputri, S.; Bechauf, R.; Casier, L. *Green Public Procurement in Indonesia: Policies, Practices, and Ways Forward*; International Institute for Sustainable Development: Winnipeg, MB, Canada, 2024.
5. UNDOC. Public Procurement Reform in Indonesia. Available online: <https://www.unodc.org/roseap/en/what-we-do/anti-corruption/topics/2020/public-procurement-reform-indonesia.html> (accessed on 17 February 2025).
6. Jin, X.; Azam, S.M.F.; Tham, J. Challenges of Sustainable Public Procurement in Chinese Higher Education Institutions: A Delphi Study. *J. Public Procure.* **2024**, *24*, 371–392. <https://doi.org/10.1108/JOPP-05-2024-0051>.
7. Jacob Nsiah-Sarfo, D.; Ofori, D.; Agyapong, D. Sustainable Procurement Implementation among Public Sector Organisations in Ghana: The Role of Institutional Isomorphism and Sustainable Leadership. *Clean. Logist. Supply Chain* **2023**, *8*, 100118. <https://doi.org/10.1016/j.clscn.2023.100118>.
8. dos Santos, A.L.T.; da Cunha Reis, A. *Public Procurement from the Triple Bottom Line Lens: The Identification of Sustainability Criteria from the International Literature Review*; Springer: Dordrecht, Netherlands, 2024; ISBN 0123456789.
9. Torkki, P.; Rotinen, L.; Taponen, S.; Tella, S.; Grönman, K.; Deviatkin, I.; Pitkänen, L.J.; Venesoja, A.; Koljonen, K.; Repo, E.; et al. Increasing the Role of Sustainability in Public Procurement of Personal Protective Equipment. *J. Clean. Prod.* **2024**, *455*, 142335. <https://doi.org/10.1016/j.jclepro.2024.142335>.
10. Dragos, D.; Neamtu, B. Sustainable Public Procurement: Life Cycle Costing (LCC) in the New EU Directive Proposal. *Eur. Procure. Public Priv. Partnersh. Law Rev.* **2013**, *8*, 19–30.
11. Li, R.; Cao, F. The Impact of Sustainable Public Procurement on Corporate ESG Performance—The Chinese Evidence. *PLoS ONE* **2023**, *18*, e0292286. <https://doi.org/10.1371/journal.pone.0292286>.
12. De Giacomo, M.R.; Testa, F.; Iraldo, F.; Formentini, M. Does Green Public Procurement Lead to Life Cycle Costing (LCC) Adoption? *J. Purch. Supply Manag.* **2019**, *25*, 100500. <https://doi.org/10.1016/j.pursup.2018.05.001>.
13. Orfanidou, V.S.; Rachaniotis, N.P.; Tsoulfas, G.T.; Chondrokoukis, G.P. Life Cycle Costing Implementation in Green Public Procurement: A Case Study from the Greek Public Sector. *Sustainability* **2023**, *15*, 2817. <https://doi.org/10.3390/su15032817>.
14. Wurster, S.; Ladu, L. Triple-C: A Tridimensional Sustainability-Oriented Indicator for Assessing Product Circularity in Public Procurement. *Sustainability* **2022**, *14*, 13936. <https://doi.org/10.3390/su142113936>.
15. Luttenberger, A. Sustainable Procurement and Environmental Life-Cycle Costing in Maritime Transport. *WMU J. Marit. Aff.* **2017**, *16*, 219–231. <https://doi.org/10.1007/s13437-016-0116-6>.
16. Alkadry, M.G.; Trammell, E.; Dimand, A.M. The Power of Public Procurement: Social Equity and Sustainability as Externalities and as Deliberate Policy Tools. *Int. J. Procure. Manag.* **2019**, *12*, 336–362. <https://doi.org/10.1504/IJPM.2019.099553>.
17. Brammer, S.; Walker, H. Sustainable Procurement in the Public Sector: An International Comparative Study. *Int. J. Oper. Prod. Manag.* **2011**, *31*, 452–476. <https://doi.org/10.1108/01443571111119551>.
18. Grandia, J.J.; Kruijen, P.M.P. Assessing the Implementation of Sustainable Public Procurement Using Quantitative Text-Analysis Tools: A Large-Scale Analysis of Belgian Public Procurement Notices. *J. Purch. Supply Manag.* **2020**, *26*, 100627. <https://doi.org/10.1016/j.pursup.2020.100627>.
19. Thai, K.V. Public Procurement Re-Examined. *J. Public Procure.* **2001**, *1*, 9–50.
20. Tarantini, M.; Loprieno, A.D.; Porta, P.L. A Life Cycle Approach to Green Public Procurement of Building Materials and Elements: A Case Study on Windows. *Energy* **2011**, *36*, 2473–2482. <https://doi.org/10.1016/j.energy.2011.01.039>.
21. Asian Development Bank. Sustainable Public Procurement. In *Guidance Note on Procurement*; Asian Development Bank: Manila, Philippines, 2021; Volume 38, ISBN 9789292692711.
22. Berg, A.; Alhola, K.; Peltomaa, J.; Tietari, S. Developing Together: The Finnish Way of Promoting Sustainable Public Procurement. *J. Public Procure.* **2022**, *22*, 245–264. <https://doi.org/10.1108/JOPP-11-2021-0072>.
23. Etse, D.; McMurray, A.; Muenjohn, N. Comparing Sustainable Public Procurement in the Education and Health Sectors. *J. Clean. Prod.* **2021**, *279*, 123959. <https://doi.org/10.1016/j.jclepro.2020.123959>.
24. Ahsan, K.; Rahman, S. Green Public Procurement Implementation Challenges in Australian Public Healthcare Sector. *J. Clean. Prod.* **2017**, *152*, 181–197. <https://doi.org/10.1016/j.jclepro.2017.03.055>.

25. Hunka, A.; Vanacore, E.; Mellquist, A.; Fuertes-Gine, L. How to Increase the Uptake of Circular Public Procurement? Lessons Learned from Local Authorities in Sweden. *J. Public Procure.* **2023**, *23*, 245–271. <https://doi.org/10.1108/JOPP-08-2022-0039>.
26. Liu, J.; Shi, B.; Xue, J.; Wang, Q. Improving the Green Public Procurement Performance of Chinese Local Governments: From the Perspective of Officials' Knowledge. *J. Purch. Supply Manag.* **2019**, *25*, 100501. <https://doi.org/10.1016/j.pursup.2018.05.002>.
27. Liu, J.; Xue, J.; Yang, L.; Shi, B. Enhancing Green Public Procurement Practices in Local Governments: Chinese Evidence Based on a New Research Framework. *J. Clean. Prod.* **2019**, *211*, 842–854. <https://doi.org/10.1016/j.jclepro.2018.11.151>.
28. Knebel, S.; Seele, P. Framing Sustainability in Public Procurement by Typologizing Sustainability Indicators—The Case of Switzerland. *J. Public Procure.* **2021**, *21*, 119–137. <https://doi.org/10.1108/JOPP-09-2020-0066>.
29. Benckekroun, H.T.; Benmamoun, Z.; Hachimi, H. Implementation and Sustainability Assessment of a Public Procurement Strategy. *Sustainability* **2022**, *14*, 15565. <https://doi.org/10.3390/su142315565>.
30. de Souza Silva Oliveira, M.V.; Simão, J.; da Silva Caeiro, S.S.F. Stakeholders' Categorization of the Sustainable Public Procurement System: The Case of Brazil. *J. Public Procure.* **2020**, *20*, 423–449. <https://doi.org/10.1108/JOPP-09-2018-0031>.
31. Kristensen, H.S.; Mosgaard, M.A.; Remmen, A. Circular Public Procurement Practices in Danish Municipalities. *J. Clean. Prod.* **2021**, *281*, 124962. <https://doi.org/10.1016/j.jclepro.2020.124962>.
32. Sönnichsen, S.D.; Clement, J. Review of Green and Sustainable Public Procurement: Towards Circular Public Procurement. *J. Clean. Prod.* **2020**, *245*, 118901. <https://doi.org/10.1016/j.jclepro.2019.118901>.
33. Von Deimling, C.; Essig, M.; Schaupp, M.; Amann, M.; Vafai, S. Life-Cycle-Cost-Management as an Instrument for Strategic Public Procurement: State of the Art and Perspectives. In Proceedings of the 25th Annual IPSERA Conference, Dortmund, Germany, 20–23 March 2016.
34. Gaus, J.; Wehking, S.; Glas, A.H. Economic Sustainability by Using Life Cycle Cost Information in the Buying Center: Insights from the Public Sector. *Sustainability* **2022**, *14*, 1871.
35. Bibire, L.; Chitimus, A.D.; Ghenadi, A.S. Multi-Criteria Assessment of Taxi Transport Services for Public Procurement: Case Study for Bacau City. *Sustainability* **2023**, *15*, 7489. <https://doi.org/10.3390/su15097489>.
36. Moore, M.H. *Creating Public Value: Strategic Management in Government*; Harvard University Press: Cambridge, MA, USA, 1995.
37. Kara, K.; Acar, A.Z.; Polat, M. Developing a Hybrid Methodology for Green-Based Supplier Selection: Application in the Automotive Industry. *Expert Syst. Appl.* **2024**, *249*, 123668. <https://doi.org/10.1016/j.eswa.2024.123668>.
38. Saputro, T.E.; Rosiani, T.Y.; Mubin, A.; Dewi, S.K.; Baroto, T. Green Supplier Selection under Supply Risks Using Novel Integrated Fuzzy Multi-Criteria Decision Making Techniques. *J. Clean. Prod.* **2024**, *449*, 141788. <https://doi.org/10.1016/j.jclepro.2024.141788>.
39. Mabrouk, N. Ben Green Supplier Selection Using Fuzzy Delphi Method for Developing Sustainable Supply Chain. *Decis. Sci. Lett.* **2021**, *10*, 63–70. <https://doi.org/10.5267/j.dsl.2020.10.003>.
40. Ghosh, S.; Bhowmik, C.; Sinha, S.; Raut, R.D.; Chandra, M.; Ray, A. An Integrated Multi-Criteria Decision-Making and Multi-variate Analysis towards Sustainable Procurement with Application in Automotive Industry. *Supply Chain Anal.* **2023**, *3*, 100033. <https://doi.org/10.1016/j.sca.2023.100033>.
41. Liou, J.J.H.; Chang, M.; Lo, H.; Hsu, M. Application of an MCDM Model with Data Mining Techniques for Green Supplier Evaluation and Selection. *Appl. Soft Comput.* **2021**, *109*, 107534. <https://doi.org/10.1016/j.asoc.2021.107534>.
42. Ghosh, S.; Bhowmik, C.; Mandal, M.C.; Ray, A. Green Supplier Selection: An Empirical Investigation. In *Modelling, Simulation and Optimization*; Springer: Singapore, 2021; ISBN 9789811598289.
43. Neto, B. Analysis of Sustainability Criteria from European Public Procurement Schemes for Foodservices. *Sci. Total Environ.* **2020**, *704*, 135300. <https://doi.org/10.1016/j.scitotenv.2019.135300>.
44. Namayala, P.P.; Kondo, T.S. Application of Fuzzy Delphi Technique to Identify Analytical Lenses for Determining the Preparation of Free and Open Source Software Projects for User Experience Maturity. *Sci. Comput. Program.* **2024**, *237*, 103136. <https://doi.org/10.1016/j.scico.2024.103136>.
45. Padilla-Rivera, A.; Barros, B.; Arcese, G.; Merveille, N. Social Circular Economy Indicators: Selection through Fuzzy Delphi Method. *Sustain. Prod. Consum.* **2021**, *26*, 101–110. <https://doi.org/10.1016/j.spc.2020.09.015>.
46. Oteng, D.; Zuo, J.; Sharifi, E. An Expert-Based Evaluation on End-of-Life Solar Photovoltaic Management: An Application of Fuzzy Delphi Technique. *Sustain. Horiz.* **2022**, *4*, 100036. <https://doi.org/10.1016/j.horiz.2022.100036>.
47. Van Wee, B.; Banister, D. How to Write a Literature Review Paper? *Transp. Rev.* **2016**, *36*, 278–288. <https://doi.org/10.1080/01441647.2015.1065456>.
48. Jia, F.; Yin, S.; Chen, L.; Chen, X. The Circular Economy in the Textile and Apparel Industry: A Systematic Literature Review. *J. Clean. Prod.* **2020**, *259*, 120728. <https://doi.org/10.1016/j.jclepro.2020.120728>.

49. Xu, L.; Jia, F.; Yan, F.; Chen, L. Circular Procurement: A Systematic Literature Review. *J. Clean. Prod.* **2022**, *365*, 132845. <https://doi.org/10.1016/j.jclepro.2022.132845>.
50. Moradpour, N.; Pourahmad, A.; Ziari, K.; Hataminejad, H.; Sharifi, A. Downscaling Urban Resilience Assessment: A Spatio-temporal Analysis of Urban Blocks Using the Fuzzy Delphi Method and K-Means Clustering. *Build. Environ.* **2024**, *263*, 111898. <https://doi.org/10.1016/j.buildenv.2024.111898>.
51. Cheng, C.-H.; Lin, Y. Evaluating the Best Main Battle Tank Using Fuzzy Decision Theory with Linguistic Criteria Evaluation. *Eur. J. Oper. Res.* **2002**, *142*, 174–186.
52. Bodjanova, S. Median Alpha-Levels of a Fuzzy Number. *Fuzzy Sets Syst.* **2006**, *157*, 879–891. <https://doi.org/10.1016/j.fss.2005.10.015>.
53. Dahlgren, S.; Ammenberg, J. Sustainability Assessment of Public Transport, Part II—Applying a Multi-Criteria Assessment Method to Compare Different Bus Technologies. *Sustainability* **2021**, *13*, 1273. <https://doi.org/10.3390/su13031273>.
54. Sheth, A.; Sarkar, D. Life Cycle Cost Analysis for Electric vs. Diesel Bus Transit in an Indian Scenario. *Int. J. Technol.* **2019**, *10*, 105–115. <https://doi.org/10.14716/ijtech.v10i1.1958>.
55. Perera, O.; Morton, B.; Perfrement, T. *Life Cycle Costing in Sustainable Public Procurement—A Question of Value*; The International Institute for Sustainable Development: Winnipeg, MB, Canada, 2009.
56. C.D. Howe Institute. *Rebuilding Better: Local Content and Public Procurement Rules Featuring an Action Agenda for Policymakers*; C.D. Howe Institute: Toronto, ON, Canada, 2021.
57. The European Parliament; The Council of the European Union. *Directive 2014/24/EU of The European Parliament and of The Council of 26 February 2014 on Public Procurement and Repealing Directive 2004/18/EC*; Official Journal of the European Union: Luxembourg, 2014; pp. 65–242.
58. Singh, P.; Mulpuri, S.K.; Kumar, P.; Bhagavathula, S. A Commercial Analysis for Sustainable Public Transit Procurement Approach in India's Buses Electrification Drive. *2024 IEEE Transp. Electrif. Conf. Expo ITEC 2024*, **2024**, 1–6. <https://doi.org/10.1109/ITEC60657.2024.10598869>.
59. Schlipf, M.; Keller, C.; Lutzenberger, F.; Pfossner, S.; Rathgeber, A. Measuring Life Cycle Costs for Complex B2B Products: A Novel, Integrated and Practical Methodology across Disciplines for Pricing Maintenance Contracts. *J. Qual. Maint. Eng.* **2019**, *25*, 355–375. <https://doi.org/10.1108/JQME-12-2017-0086>.
60. European Commission. *User Guide to the Life Cycle Costing Tool for Green Public Procurement of Imaging Equipment*; European Commission: Brussels, Belgium, 2019.
61. Felipe, D.; Oliveira, D.; Gabbay, R.; Souza, D. Life Cycle Sustainability Impact Categories for Sustainable Procurement. *J. Clean. Prod.* **2023**, *383*, 135448. <https://doi.org/10.1016/j.jclepro.2022.135448>.
62. Keulemans, S.; Van de Walle, S. Cost-Effectiveness, Domestic Favouritism and Sustainability in Public Procurement: A Comparative Study of Public Preferences. *Int. J. Public Sect. Manag.* **2017**, *30*, 328–341. <https://doi.org/10.1108/IJPSM-10-2016-0169>.
63. Brusselaers, J.; Bracquene, E.; Peeters, J.; Dams, Y. Economic Consequences of Consumer Repair Strategies for Electrical Household Devices. *J. Enterp. Inf. Manag.* **2020**, *33*, 747–767. <https://doi.org/10.1108/JEIM-12-2018-0283>.
64. Saccani, N.; Perona, M.; Bacchetti, A. The Total Cost of Ownership of Durable Consumer Goods: A Conceptual Model and an Empirical Application. *Int. J. Prod. Econ.* **2017**, *183*, 1–13. <https://doi.org/10.1016/j.ijpe.2016.09.021>.

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