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A Sustainable Supplier Selection Adapting Triple Bottom Line Framework for The Construction Industry using Multi-Criteria Decision-Making

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Abstract

Nowadays, the call to go green is getting stronger than ever. Numerous environmental issues are constantly arising, leading to various laws and regulations to address the problem. Companies and organizations are trying to integrate sustainability into their business processes. The construction industry, one of the largest industries, also encounters the same scenario. This study aims to bridge the gap between sustainability and the construction industry by developing a sustainable supplier selection tool. The researchers chose the country of the Philippines as the location. Sustainability is incorporated using the triple bottom-line framework. The triple-bottom-line framework consists of environmental, economic, and social dimensions. This framework allows a holistic view of the necessary things for prioritization and not on profitability alone. Existing literature and studies were found to determine the sub-criteria for each of the three dimensions. The economic dimension garnered a total of 15 sub-criteria, the social dimension has a total of 10 sub-criteria, and 12 sub-criteria were determined for the environmental dimension, which sums up to 37 sub-criteria. A total of 100 respondents have participated with online survey questionnaires. Using factor analysis, the researchers were able to compress the 37 sub-criteria into eight sub-criteria: four sub-criteria under economic criterion, two sub-criteria under social criterion, and two sub-criteria under environmental criterion. Moreover, Analytical Hierarchy Process (AHP), a multi-criteria decision-making (MCDM) tool, was employed to determine the relative weights, which corresponds to importance, of each sub-criterion. At the end, the researchers were able to develop a tool using Excel Visual Basic Application to determine the best sustainable supplier given the set of criteria.

Keywords
Sustainable Supplier, Supplier Selection, Triple Bottom Line, Construction Industry, Multi-Criteria Decision-Making (MCDM), Analytical Hierarchy Process (AHP)

1. Introduction
In recent years, concerns about global warming, natural resource depletion, and energy consumption have risen (One Planet Network n.d.). Globally, the consumption of resources and energy is outpacing both population and economic growth, indicating that many resources and energy are used inefficiently. These unsustainable consumptions and practices have a critical impact on the environment and socio-economic, such as climate change, biodiversity loss, pollution, and loss of livelihood. The supply chain has significantly contributed to unsustainable consumption and practices (Luther 2021). With the sourcing of raw materials, production, inventory, and transportation and delivery, the supply chain frequently produces unnecessary waste. Thus, the government, non-government, and private organizations worldwide strive to minimize the impacts industries have on the environment, society, and economy by developing sustainable supply chain management.

Among various industry sectors, the construction industry is considered one of the world's largest consumers of resources and waste generators. Around two-fifths of the world's energy and materials flow, one-sixth of freshwater reserves, and one-quarter of worldwide wood harvest are projected to be used by the construction industry (Turkyilmaz et al. 2019). Moreover, the construction industry generates an estimated 30% of total waste (BigRentz, Inc. 2022) and

40% of greenhouse gas emissions globally (Müller et al. 2020). Waste stream records industrial construction wastes from concrete, cinder blocks, gypsum, masonry, asphalt, wood shingles, slate, metals, glass, and plaster (Zero Waste Scotland. n.d.). Some of these materials are cost-effective to recycle, and some are less reusable. Therefore, substantially more waste ends up in landfills.

In the Philippines, urbanization is growing at high speed, which entails increased infrastructure demand, and a volume increase of construction works (Nicolas 2018). According to a 2017 report by Oxford Business Group, sustainability has become a relevant component of building design and construction in the country to reduce negative impacts and boost business yield. In this call to go green, the process of manufacturing building materials is as necessary as the regulations and practices in construction. The report added that cement production contributes to about 5-7% of global CO2 emissions, iron, and steel production accounts for 11% of global CO2 emissions, and aluminum production uses more than 5% of the world's electrical energy. Thus, building materials suppliers play a significant role in the success of a sustainable supply chain in the construction industry. Suppliers should not be chosen solely based on pricing, delivery, and service quality; they should also be able to integrate sustainability into their business processes (Salam & Ali 2020).

In implementing the sustainable supplier selection tool, existing related literature does not explore the application of sustainable supplier selection adapting the triple bottom line in the Philippine construction industry. Also, existing related works of literature only explore sustainable supplier selection in the construction industry using fuzzy-based approaches and AHP-TOPSIS method to develop sustainable supplier selection in other industries. With the increasing construction works happening in the Philippines due to the developing economy, the researchers developed a sustainable supplier selection tool for the Philippine construction industry using Multi-Criteria Decision Making that considers the following: (1) social dimension, (2) economic dimension, and (3) environmental dimension.

2. Literature Review

2.1 Triple Bottom Line

Triple bottom line is a sustainability framework coined by John Elkington to measure the performance of businesses in America during his time. There are three categories: people, planet, and profit. In some articles, the planet may be represented as the environment, people as social, and profit as prosperity. The people category measures how socially responsible a company has been. It is not limited to the shareholders of the company, which are traditionally favored in businesses. This view shifts the company's focus to the people and communities affected by their decisions. As a way of giving back to the community, jobs and opportunities are given. The planet category focuses on environmental responsibilities. Businesses are among the main contributors to climate change. Therefore, changing traditional ways by embracing eco-friendly alternatives will surely give significant change from the environment. Lastly, profit measures the gain and loss of the company (Kenton 2022). This sustainability framework ensures that profit is not made at the expense of environmental and social sustainability.

2.2 Sustainable Supplier Selection

Supplier selection is a critical strategic decision made by supply chain managers (Roy et al. 2019). Supplier selection requires the assessment of alternative suppliers based on different criteria, which could improve the firm's overall performance and competitiveness (Cristea & Cristea 2017). Selecting suitable suppliers could minimize cost, increase profit, improve product quality, enhance customer satisfaction, and reduce negative environmental impact (Abdollahi et al. 2015). Supplier selection is a complex problem that involves a large number of suppliers and requires a decision-making approach. This process consists of three significant steps (Taherdoost & Brard 2019). First is the identification of selection criteria which is traditionally about quality, cost, reliability, and delivery performance. However, due to globalization and sustainability issues, firms added the three pillars of sustainability - environmental, social, and economic - as the main selection criteria (Roy et al. 2019). Second is the deployment of survey questionnaires on procurement managers to determine the weights of the main criteria and sub-criteria. Third, choose the appropriate supplier selection method to determine the best supplier among all alternatives.

With the integration of three pillars of sustainability, namely, environmental, social, and economical, the selection criteria have become more complex but still as important in the selection process. Supplier selection criteria from various works of literature were gathered and listed in Table 1. Each sub-criterion is provided with a description.

Table 1. Criteria for Sustainable Supplier Selection

Criteria	Description	References
Economic Criteria		
Price	Include unit price, pricing terms, exchange rates, taxes, and discounts.	(Wang Chen et al., 2016), (Matić et al., 2019), (Taherdoost & Brard, 2019), (Hoseini et al., 2021)

Cost	The cost is a monetary valuation of effort, material, resources, time, and utilities consumed, risks incurred, and opportunity forgone in producing and delivering a good or service.	(Mahmood et al., 2014), (Wang Chen et al., 2016), (Taherdoost & Brard, 2019)
Quality	Quality-related certificates, warranties and claim policies, and repair and return rate, and the supplier's ability to consistently meet quality specifications, including quality features (material, dimensions, design, durability), variety, production quality (production lines, manufacturing techniques, machinery), quality system, and continuous improvement.	(Mahmood et al., 2014), (Wang Chen et al., 2016), (Matić et al., 2019), (Taherdoost & Brard, 2019), (Hoseini et al., 2021)
Delivery	The ability of the supplier to meet specified delivery schedules, which include lead-time, on-time performance, safety, and security of components, fill rate, returns management, location, transportation, and incoterms.	(Mahmood et al., 2014), (Wang Chen et al., 2016), (Matić et al., 2019), (Taherdoost & Brard, 2019), (Hoseini et al., 2021)
Service	The ability of suppliers to provide intangible products, including customization, minimum order quantity, product handling, product identification and traceability, customer complaint handling, post-market surveillance, the capability of handling on time, and technology support.	(Mahmood et al., 2014), (Taherdoost & Brard, 2019), (Hoseini et al., 2021)
Technology Capability	The ability to acquire new technologies and technical resources for research and development practices and processes.	(Mahmood et al., 2014), (Wang Chen et al., 2016), (Matić et al., 2019), (Taherdoost & Brard, 2019), (Hoseini et al., 2021)
Flexibility	Product volume changes, short setup time, conflict resolution, using flexible machines, the demand that can be profitably sustained, and time or cost required to add new products to the existing production operation.	(Wang Chen et al., 2016), (Matić et al., 2019),
Financial Capability	Financial position, economic stability, and price strategy needed to maintain normal business activities during a certain period.	(Wang Chen et al., 2016), (Matić et al., 2019), (Hoseini et al., 2021)
Partnership Relations	The tendency for establishing long-term relationships, close business relations with suppliers to fully develop the market.	(Wang Chen et al., 2016), (Matić et al., 2019), (Hoseini et al., 2021)
Management and Organization	The reputability of the supplier's management team and the efficiency of their decision-making to resolve issues are practical and beneficial.	(Taherdoost & Brard, 2019)
Risk Factor	The risk factor is a measurable characteristic or element, a change that can affect the value of an asset, such as exchange rate, interest rate, and market price.	(Taherdoost & Brard, 2019)
Commercial Plans and Structure	The supplier's format statement of business goals, reasons they are attainable, and plans and infrastructure for reaching them.	(Taherdoost & Brard, 2019)
Reliability	The supplier's quality of being trustworthy and dependable based on the references (buyers' feedback), financial stability (capital, annual turnover), past and current business partners, company organization and personnel, diversity of ownership, and cultural awareness.	(Taherdoost & Brard, 2019)
Process Improvement	The supplier's ability to identify, analyze, and improve upon existing business processes within its company for optimization and to meet new quotas or standards of quality.	(Taherdoost & Brard, 2019)
Product Development	The ability of a supplier to modify an existing product or its presentation or formulation of an entirely new product that satisfies a newly defined customer want or market niche.	(Taherdoost & Brard, 2019)
Social Criteria		
Safety and Health	Concerning the safety, health, and welfare issues.	(Mahmood et al., 2014), (Matić et al., 2019), (Hoseini et al., 2021)
Training of Employees	The process of enhancing employees' skills, capabilities, and knowledge for a particular job.	(Mahmood et al., 2014), (Matić et al., 2019), (Hoseini et al., 2021)
Reputation	Reputation shows the general opinion of the suppliers relating to their reputation.	(Matić et al., 2019), (Hoseini et al., 2021)
Employees' Rights	A group of legal rights claimed human rights have to do with labor relations between workers and their employers.	(Matić et al., 2019), (Hoseini et al., 2021)
Employees' Interest	Concerning the employees' issues and requirements for achieving sustainable effectiveness in the long term.	(Hoseini et al., 2021)
Local Community Influence	Close relations between the firm and the local state, the community, and all residents, represent the public figure of the organization.	(Matić et al., 2019), (Hoseini et al., 2021)

Respect of Rights and Policies	Firms comply with all laws and regulations of the country, observe legal obligations, and promote good social public morals.	(Matić et al., 2019), (Hoseini et al., 2021)
Disclosing Information	Presenting information to stakeholders about the materials used, carbon emissions, toxins released during production, etc.	(Matić et al., 2019), (Hoseini et al., 2021)
Stakeholders' Rights	Concerning the moral rights of people with stakes in the business.	(Hoseini et al., 2021)
Labor Relations Record	The supplier's relationship between management and its workforce.	(Taherdoost & Brard, 2019)
Environmental Criteria		
Waste Management and Pollution Control	The raw material is such that while producing the product, wastage and pollution should be minimal.	(Mahmood et al., 2014), (Wang Chen et al., 2016), (Matić et al., 2019), (Hoseini et al., 2021)
Green Image	The identity that consumers prioritize environmental conservation and sustainable business practices.	(Mahmood et al., 2014), (Wang Chen et al., 2016), (Matić et al., 2019)
Green Competency	The ability to modify products, raw materials, processes, and technologies to reduce the impact on natural resources, social responsibility, and green process.	(Wang Chen et al., 2016), (Matić et al., 2019)
Green Product	Environmentally conscious products which are pollution-free, green packaging, cost and resource-saving, and renewable and recyclable.	(Wang Chen et al., 2016), (Matić et al., 2019)
Pollution Production	The average volume of air pollutants, wastewater, solid waste, and harmful materials released.	(Wang Chen et al., 2016)
Resource Consumption	The use of non-renewable or, less often, renewable resources.	(Wang Chen et al., 2016), (Matić et al., 2019)
Eco-design	Integrate eco-friendly techniques in the design of the products to reduce environmental impacts during their whole lifecycle.	(Wang Chen et al., 2016), (Matić et al., 2019), (Hoseini et al., 2021)
Environmental Protection Management System	A system that comprehensively evaluates an organization's internal and external environmental performance with environmental certificates such as ISO 14000, continuous monitoring and regulatory compliance, environmental policies, green process planning, and internal control process.	(Wang Chen et al., 2016), (Matić et al., 2019), (Hoseini et al., 2021)
Staff Environmental Training	Staff training on environmental issues.	(Wang Chen et al., 2016)
Green Technology	The application of environmental science to conserve the natural environment and resources and curb the negative impact of human involvement.	(Wang Chen et al., 2016)
Green Management	The potential of the product for maximizing the environmental performance and management.	(Hoseini et al., 2021)
Green R&D and Innovation	The potential of suppliers for research and development activities to innovate newer, cleaner technologies, processes, techniques, and methodologies.	(Hoseini et al., 2021)

With several main criteria and sub-criteria, the multi-criteria decision-making (MCDM) approach is best for supplier selection (Mahmood et al. 2014). There are several supplier selection methods to solve an MCDM problem, such as fuzzy logic for cluster analysis: Analytic Hierarchy Process (AHP), Analytic Network Process (ANP), Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), Outranking method with Elimination and Choice Expressing Reality (ELECTREE), Preference Ranking Organization Method for Enrichment Evaluations (PROMETHEE), and Multi-Attribute Utility Theory (MAUT method) for categorical methods; Activity Based Costing and Total Cost of Ownership for costs method; Linear Programming, Goal Programming, Multi-objective Linear Programming, and Data Envelopment Analysis (DEA) for mathematical programming method (Taherdoost & Brard, 2019). In real-life situations, AHP has become a preferred method for solving MCDM problems because it can suit the qualitative and quantitative nature of the selection criteria (Taherdoost & Brard 2019).

In addition, beyond regulations and policy enforcements, different countries should adopt a holistic approach to sustainability. Accordingly, sustainability assessment has been acknowledged as a critical tool for achieving this goal and Green Rating Systems (GRSs) is one of the useful tools in achieving sustainable development. GRS offers guidelines and metrics to define how well a company complies with sustainability (Encyclopedia Journal, n.d.). The sustainability rating level of construction works based on the Building Ecological Responsive Design Excellence (BERDE) established by the Philippine Green Building Council (PHILGBC) is shown in table 2.

Table 2. BERDE Rating Levels

Score	Remarks
50 and below	Unsustainable
51 to 60	Minimum practice of sustainability
61 to 70	Good practice of sustainability
71 to 80	Exemplar practice of sustainability
81 to 90	World class practice of sustainability
91 and above	World leader practice of sustainability

3. Methods

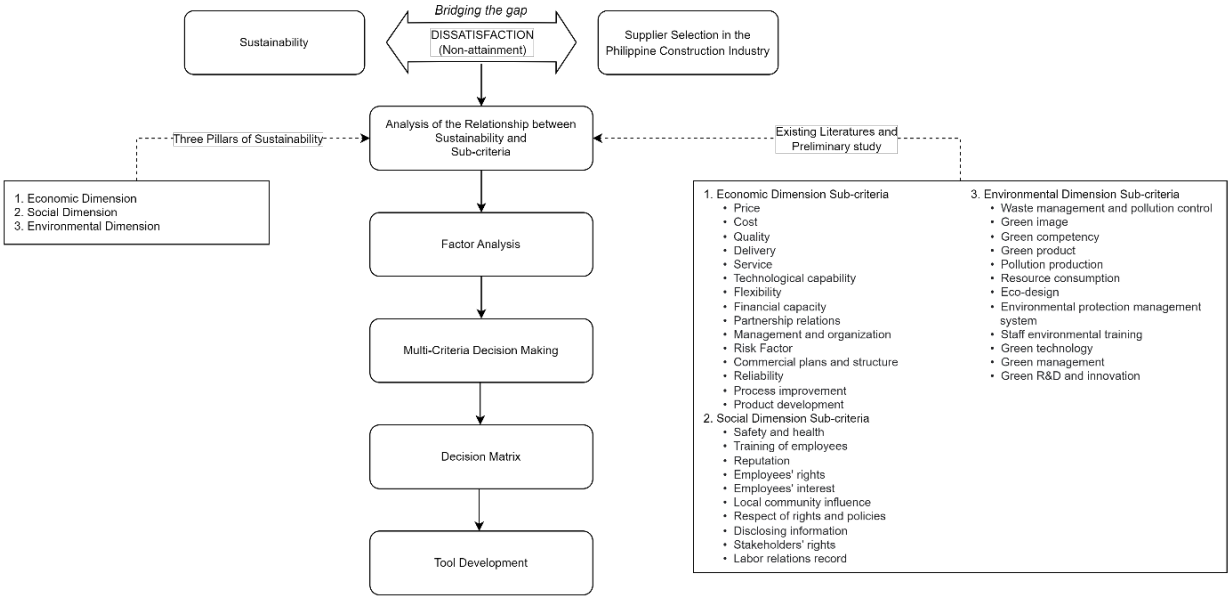

Figure 1. Research Paradigm

The study aimed to bridge the current dissatisfaction between the supplier selection of the Philippine construction industry and sustainability. The researchers analyzed the relationship between the three pillars of sustainability and its sub-criteria through an online survey. A total of 15 sub-criteria under economic criterion, 10 sub-criteria under social criterion, and 12 sub-criteria under environmental criterion were obtained from review of related literature and studies. The data gathered underwent data cleaning to remove outliers and insignificant responses from the sample to preserve the quality of the data that were used in the study. Afterward, the researchers conducted factor analysis to determine the significant and insignificant criteria and analytical hierarchy process to identify the relative weight of each criterion and sub-criterion. These analyses were performed using Microsoft Excel and SPSS Statistics. Lastly, the researchers created a decision matrix for determining the best supplier among alternatives in a construction company and developed a supplier selection tool using Excel Visual Basic for Application (Excel VBA) to aid the supplier selection process.

4. Data Collection

The researchers collected data from the survey respondents of 100, who are all professional individuals based in the Philippines with experience in construction industry materials procurement decision-making, such as project managers, operations managers, supply chain managers, and others. The online survey questionnaire was conducted via Google Forms utilizing a 6-point Likert scale to assess the criteria considered in procurement decision-making. The researchers ensured that all participants were informed of the study's purpose and significance before they agreed or declined to participate. Each participant was free to opt-in or out of the study at any time. Additionally, all forms of information were kept confidential and protected under the Republic Act of 10173 and the Data Privacy Act of 2012. Personally identifiable data was anonymized so that it cannot be linked to other data by anyone else. All raw data gathered from the participants will be deleted within five years. No harmful activities were done in the participants' data collection.

5. Results and Discussions

5.1 Factor Analysis

The researchers used SPSS Statistics in performing factor analysis which analyzed the initial data. The researchers applied the components analysis and varimax rotation of factor analysis to obtain the result. The researchers obtained the following output after conducting factor analysis:

1. Correlation matrix which indicates the correlations in the data and the appropriateness of data analysis. High values in the correlation matrix may lead to multicollinearity, where several independent variables correlate, resulting in less reliable statistical interferences.
2. Rotated component matrix which displays the variable loads of each factor after the rotation and its extent. It shows which group of variables can go together mathematically and develops a common theme that encompasses the variable.

Economic Criterion

		C1.1	C1.2	C1.3	C1.4	C1.5	C1.6	C1.7	C1.8	C1.9	C1.10	C1.11	C1.12	C1.13	C1.14	C1.15
Correlation	C1.1	1.000	.465	.368	.291	.060	.169	.073	.230	.222	.107	.123	.103	.425	.034	.174
	C1.2	.465	1.000	.254	.203	.212	.318	.011	.285	.323	-.008	.148	.248	.213	.076	.266
	C1.3	.368	.254	1.000	.286	.323	.158	.337	.187	.430	.146	.061	.155	.344	.142	.188
	C1.4	.291	.203	.286	1.000	.172	.063	.388	.255	.253	.114	.211	.090	.262	.162	.068
	C1.5	.060	.212	.323	.172	1.000	.222	.293	.429	.211	.153	.073	.262	.141	.288	.249
	C1.6	.169	.318	.158	.063	.222	1.000	.225	.346	.308	.120	.269	.310	.125	.326	.409
	C1.7	.073	.011	.337	.388	.293	.225	1.000	.452	.259	.215	.187	.366	.397	.362	.256
	C1.8	.230	.285	.187	.255	.429	.346	.452	1.000	.310	.434	.281	.327	.402	.380	.480
	C1.9	.222	.323	.430	.253	.211	.308	.259	.310	1.000	.421	.412	.414	.279	.148	.301
	C1.10	.107	-.008	.146	.114	.153	.120	.215	.434	.421	1.000	.404	.396	.314	.100	.128
	C1.11	.123	.148	.061	.211	.073	.269	.187	.281	.412	.404	1.000	.396	.258	-.021	.112
	C1.12	.103	.248	.155	.090	.262	.310	.366	.327	.414	.396	.396	1.000	.213	.126	.271
	C1.13	.425	.213	.344	.262	.141	.125	.397	.402	.279	.314	.258	.213	1.000	.298	.303
	C1.14	.034	.076	.142	.162	.288	.326	.362	.380	.148	.100	-.021	.126	.298	1.000	.430
	C1.15	.174	.266	.188	.068	.249	.409	.256	.480	.301	.128	.112	.271	.303	.430	1.000

Figure 2. Economic Criterion – Correlation Matrix

	Component			
	1	2	3	4
C1.14	.771		.179	-.101
C1.15	.716	.123		.277
C1.8	.616	.372	.280	
C1.6	.572	.279	-.168	.402
C1.5	.547		.224	
C1.11		.787		.100
C1.10		.748	.198	-.159
C1.12	.288	.683		.106
C1.9	.163	.607	.264	.310
C1.4			.707	
C1.3	.147		.636	.292
C1.13	.234	.234	.614	.127
C1.7	.477	.236	.554	-.278
C1.2	.176		.120	.820
C1.1			.497	.667

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization. [a]

a. Rotation converged in 9 iterations.

Figure 3. Economic Criterion – Rotated Component Matrix

The factor analysis under economic criterion shows the following results. The correlation matrix shows moderate correlations in the data where the correlation coefficient is greater than 0.30, which means no problem with the data set. In line with this, the rotated component matrix shows that the sub-criteria 14, 15, 8, 6, 5 and 7 are loaded into first component, sub-criteria 11, 10, 12, and 9 are loaded into second component, sub-criteria 4, 3, 13, 7 and 1 are loaded into third component, and sub-criteria 6, 2, and 1 are loaded into fourth component.

From the rotated component matrix results, the researchers were able to create a sub-criterion that includes all the variables in their respective factors. The four sub-criteria under the economic criterion are Service, Advancement, Efficiency, and Flexibility (S.A.F.E), Organizational Stability, Competitive Dimension, and Affordability and Technology.

Table 3. Economic Sub-Criteria

Component	Sub-Criteria	Description
Component 1	Service, Advancement, Efficiency, and Flexibility (S.A.F.E)	The sub-criterion consists of service, flexibility, financial capability, process improvement, and product development. It encompasses the ability of the supplier to provide intangible products and their components, and acquire new technologies and technical resources for identifying, analyzing, and improving the existing processes and modifying the products to satisfy the current market niche. In addition, it includes the financial position and the ability to sustain profitability to the existing products to maintain normal business activities for a certain time.
Component 2	Organizational Stability	It is the ability of the supplier to manage and maintain a good relationship from their partners. In connection, it involves having the capability to handle internal processes from the organization skillfully while having plans for possible improvement. Within the scope of this sub-criterion is to assess risks and develop the adequate course of action for it.
Component 3	Competitive Dimension	The sub-criterion consists of price, quality, delivery, and reliability. These are the essential operational dimensions to satisfy the internal and external customers to achieve the goal associated with the supplier's performance. The dimensions identify the course of action following the competitive priorities and prioritizing consistency.
Component 4	Affordability and Technology	The sub-criterion consists of the price, cost, and technological capability of the supplier. It describes the ability of the supplier to choose the most optimal way of producing a product at the lowest possible cost with the highest quality possible.

Social Criterion

		C2.1	C2.2	C2.3	C2.4	C2.5	C2.6	C2.7	C2.8	C2.9	C2.10
Correlation	C2.1	1.000	.478	.454	.569	.476	.299	.602	.347	.356	.493
	C2.2	.478	1.000	.462	.597	.448	.417	.541	.282	.483	.554
	C2.3	.454	.462	1.000	.396	.447	.433	.498	.241	.314	.386
	C2.4	.569	.597	.396	1.000	.730	.469	.549	.282	.516	.468
	C2.5	.476	.448	.447	.730	1.000	.466	.499	.102	.439	.346
	C2.6	.299	.417	.433	.469	.466	1.000	.403	.236	.478	.337
	C2.7	.602	.541	.498	.549	.499	.403	1.000	.567	.537	.356
	C2.8	.347	.282	.241	.282	.102	.236	.567	1.000	.353	.291
	C2.9	.356	.483	.314	.516	.439	.478	.537	.353	1.000	.494
	C2.10	.493	.554	.386	.468	.346	.337	.356	.291	.494	1.000

Figure 4. Social Criterion – Correlation Matrix

	Component	
	1	2
C2.5	.859	
C2.4	.819	.220
C2.2	.672	.358
C2.6	.661	.153
C2.3	.602	.275
C2.1	.567	.470
C2.9	.566	.433
C2.10	.548	.388
C2.8		.921
C2.7	.506	.687

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization. [a]

a. Rotation converged in 3 iterations.

Figure 5. Social Criterion – Rotated Component Matrix

The factor analysis under social criterion shows the following results. The correlation matrix shows moderate to high correlations in the data where the correlation coefficient is greater than 0.30, which means no problem with the data set. In line with this, the rotated component matrix shows that the sub-criteria 5, 4, 2, 6, 3, 1, 9, 10, and 7 are loaded into the first component, and sub-criteria 1, 9, 8, and 7 are loaded into the second component.

From the results of the rotated component matrix, the researchers were able to create a sub-criterion that includes all the variables in their respective factors. The two sub-criteria under the social criterion are Employee Management, Safety, and Health, and Adherence to Rights and Transparency.

Table 4. Social Sub-Criteria

Component	Sub-Criteria	Description
Component 1	Employee Management, Safety, and Health	The sub-criterion involves Safety and Health, Training of Employees, Reputation, Employee's Rights, Employee's Interest, Local Community Influence, Labor Relations Record. The supplier has the duty and responsibility of managing their employees through proper training, and support. It should also be imperative to impose strict health protocols to promote safety in the workplace.
Component 2	Adherence to Rights and Transparency	The sub-criterion involves Respect of Rights and Policies, Disclosing Information, and Stakeholders Rights. It is the supplier's responsibility to follow the different policies and rules established by different organizations as well as by stakeholders. They should also be willing to disclose any kind of information relevant upon making a transaction with anyone.

Environmental Criterion

		C3.1	C3.2	C3.3	C3.4	C3.5	C3.6	C3.7	C3.8	C3.9	C3.10	C3.11	C3.12
Correlation	C3.1	1.000	.409	.363	.300	.424	.289	.293	.568	.508	.368	.247	.204
	C3.2	.409	1.000	.542	.583	.323	.144	.344	.434	.310	.290	.327	.313
	C3.3	.363	.542	1.000	.543	.347	.241	.424	.436	.415	.422	.473	.186
	C3.4	.300	.583	.543	1.000	.363	.483	.316	.386	.291	.447	.365	.399
	C3.5	.424	.323	.347	.363	1.000	.481	.374	.342	.405	.367	.400	.329
	C3.6	.289	.144	.241	.483	.481	1.000	.347	.405	.317	.419	.459	.321
	C3.7	.293	.344	.424	.316	.374	.347	1.000	.522	.516	.675	.589	.393
	C3.8	.568	.434	.436	.386	.342	.405	.522	1.000	.574	.548	.547	.431
	C3.9	.508	.310	.415	.291	.405	.317	.516	.574	1.000	.593	.592	.356
	C3.10	.368	.290	.422	.447	.367	.419	.675	.548	.593	1.000	.659	.437
	C3.11	.247	.327	.473	.365	.400	.459	.589	.547	.592	.659	1.000	.403
	C3.12	.204	.313	.186	.399	.329	.321	.393	.431	.356	.437	.403	1.000

Figure 6. Environmental Criterion – Correlation Matrix

	Component	
	1	2
C3.10	.815	.216
C3.11	.795	.207
C3.7	.756	.201
C3.9	.723	.261
C3.8	.644	.426
C3.6	.589	.205
C3.12	.562	.213
C3.5	.484	.391
C3.2	.112	.863
C3.4	.271	.745
C3.3	.287	.726
C3.1	.347	.545

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.[a]

a. Rotation converged in 3 iterations.

Figure 7. Environmental Criterion – Rotated Component Matrix

The factor analysis under environmental criterion shows the following results. The correlation matrix shows low to moderate correlations in the data where the correlation coefficient is greater than 0.30, which means no problem with the data set. In line with this, the rotated component matrix shows that the sub-criteria 10, 11, 7, 9, 8, 6, 12 and 5 are loaded into the first component, and sub-criteria 8, 2, 4, 3 and 1 are loaded into the second component.

From the rotated component matrix results, the researchers were able to create a sub-criterion that includes all the variables in their respective factors. The two sub-criteria under the environmental criterion are Green Innovation Practices and Environmental Corporate Responsibility.

Table 5. Environmental Sub-Criteria

Component	Sub-Criteria	Description
Component 1	Green Innovation Practices	The sub-criterion involves pollution production, resource consumption, eco-design, environmental protection management system, staff environmental training, green technology, green management, and green R&D and innovation. It is the practices done by the suppliers to ensure its green innovation towards newer and cleaner technologies and methodologies by maximizing the environmental performance and management integrating eco-friendly techniques and design in reducing environmental impacts.
Component 2	Environmental Corporate Responsibility	The sub-criterion involves waste management and pollution control, green image, green competency, and green product. It addresses the supplier's way of managing and monitoring its environmental impacts by minimizing and controlling the by-products prioritizing environmental conservation in creating and modifying products into environmentally conscious products.

5.2 Analytical Hierarchy Process

The researchers executed Analytical Hierarchy Process (AHP), a multi-criteria decision-making technique developed by Saaty, L. in the 1970s, to determine the relative weights of each criterion and sub-criterion. The AHP analyzed decisions by ranking and providing weights from a set of attributes using an intensity scale from 1 to 9 shown in table 6, with a higher intensity signifying better performance.

Table 6. Intensity Scale for Pairwise Comparison

Relative Intensity	Importance	Description
1 and 9	Extremely Favors	One Criteria is extremely more important than the other
2 and 8	Strongly Favors	One Criteria is strongly more important than the other
3 and 7	Moderately Favors	One Criteria is moderately more important than the other
4 and 6	Slightly Favors	One Criteria is slightly more important than the other
5	Equally Favors	Both criteria are equally important

From the pairwise comparison, the researchers were able to calculate the relative importance between each criterion and sub-criterion for the decision matrix. For the main criteria, the economic criterion had a relative weight of 57%, the social criterion had a relative weight of 27%, and the environmental criterion had a relative weight of 16%. For the economic sub-criterion, S.A.F.E had a relative weight of 21%, organizational stability had a relative weight of 34%, and competitive dimension and affordability and technology both had a relative weight of 22%. For the social sub-criterion, employee management, safety, and health had a relative weight of 23%, and adherence to rights and transparency with a relative weight of 77%. Lastly, for the environmental sub-criterion, green innovation practices had a relative weight of 17%, and environmental corporate responsibility had a relative weight of 83%. Figure 8 illustrated the resulting AHP model and table 7 shows the decision matrix extracted from the AHP model.

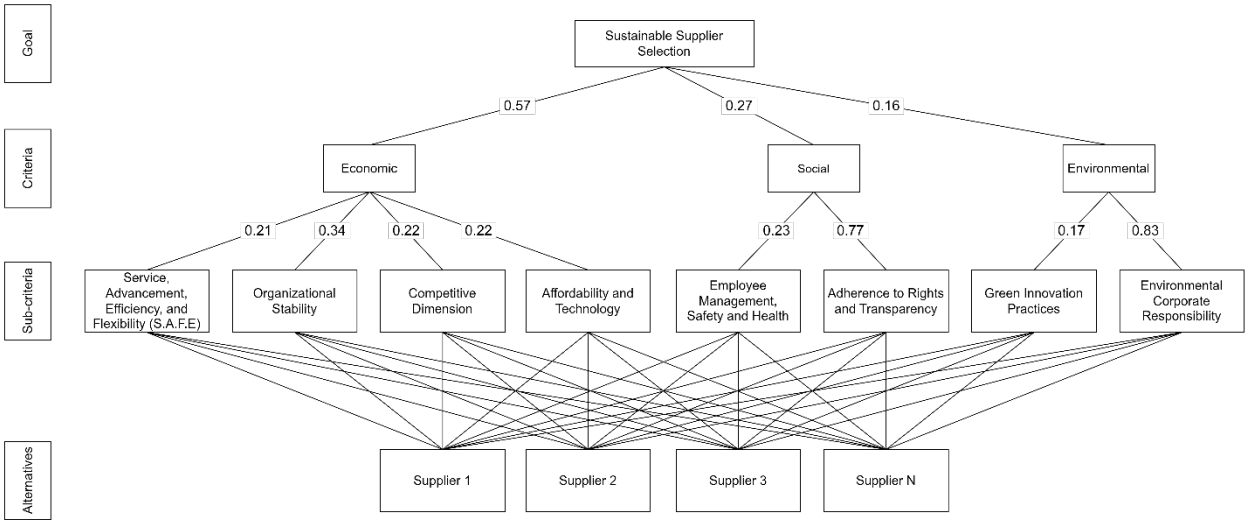

Figure 8. Analytical Hierarchy Process Model

Table 7. Sustainable Supplier Selection Decision Matrix

Criteria	Weight		Sub Weight
Economic	57%		
Service, Advancement, Efficiency, and Flexibility (S.A.F.E)			21%
Organizational Stability			34%
Competitive Dimension			22%
Affordability and Technology			22%
Social	27%		
Employee Management, Safety, and Health			23%
Adherence to Rights and Transparency			77%
Environmental	16%		
Green Innovation Practices			17%
Environmental Corporate Responsibility			83%

5.3 Tool Development

The researchers used the results of the data analysis to develop a sustainable supplier selection tool using Excel VBA. Excel VBA is commonly used to automate processes and customize applications to meet the unique requirements of a business (Schmidt, 2022) which was highly advantageous to the study because supplier selection may be a repetitive and routine task. The tool developed was divided into three interfaces: How to Use, Supplier Information, and Supplier Selection. The How to Use interface comprises the work instruction and the decision matrix. The Supplier Information interface allows the user to compile the list of available suppliers and their information. Lastly, the Supplier Selection interface allows the user to evaluate the suppliers.

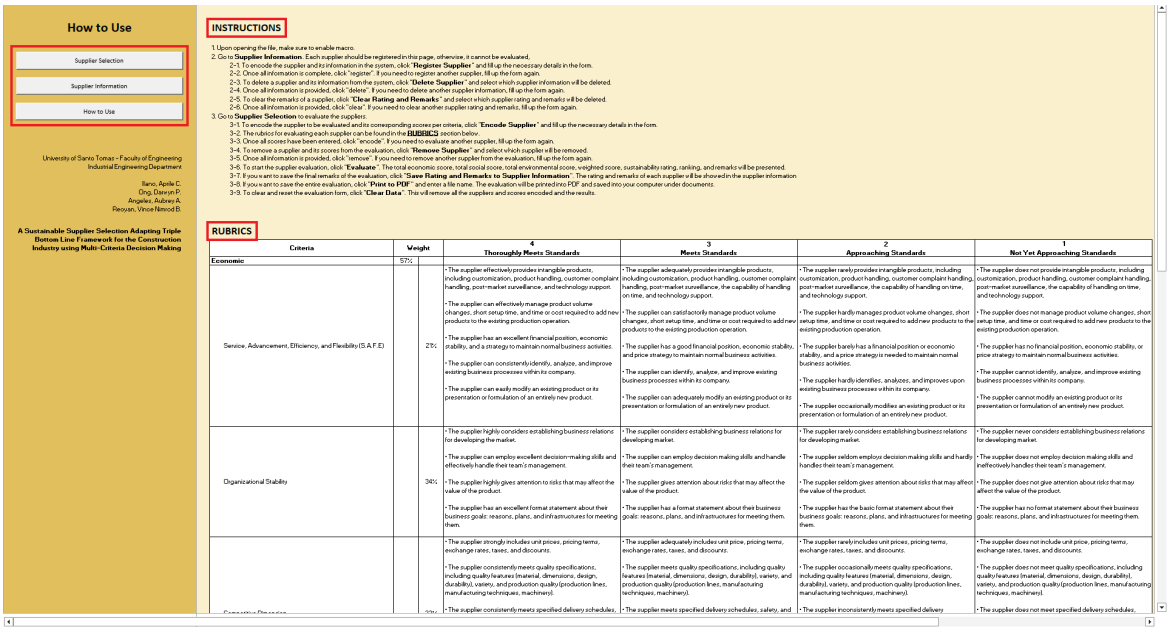

Figure 9. How to Use Interface

Upon opening the software, the How to Use interface will appear to let the user know the work instruction and rubrics. The three command buttons on the upper-left hand-side of each interface will allow the user to navigate through the different interfaces. The "How to Use" button will lead the user to the How to Use interface. The "Supplier Information" button will bring the user to the Supplier Information interface. Furthermore, the "Supplier Selection" button will lead the user to the Supplier Selection Interface.

On the How to Use interface, the user can view the work instruction and the rubrics. The work instruction is a description that clarifies how to perform specific activities correctly. Its primary objective is to describe how a particular task will be carried out. At the same time, the rubrics is a scoring guide that assesses and articulates specific criteria and expectations for a supplier. The user shall score the supplier on each criterion given the relative importance of the criteria.

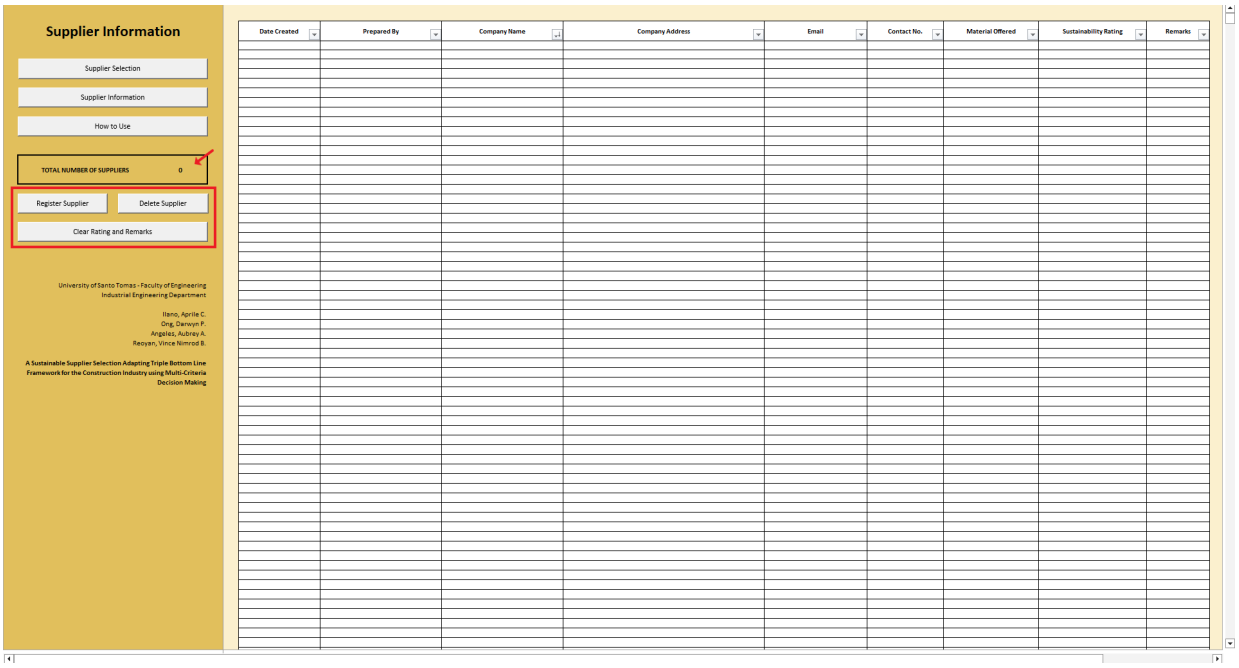

Figure 10. Supplier Information Interface

The main command button on the Supplier Information interface can be found on the left side of the interface. The user is required to register all suppliers that will be evaluated because unregistered suppliers cannot be evaluated in the Supplier Selection interface. The "Register Supplier" button will prompt a user form which the user should fill up to input a supplier in the system. The user form will ask for the date of creation, prepared by, company name, company address, email, contact number, and the material offered by the supplier. A company name and material offered were requested because a single supplier may offer various materials. Once registered, all information will appear in the interface. The "Delete Supplier" button will prompt a user form where the user can select the supplier's company name and material offered that will be deleted. Likewise, the "Clear Rating and Remarks" button will prompt a user form where user can select the supplier's company name and material offered whose rating and remarks will be deleted. Moreover, the total number of suppliers listed on the system are presented on the left side. This will allow the user to determine how many suppliers are listed on the system conveniently.

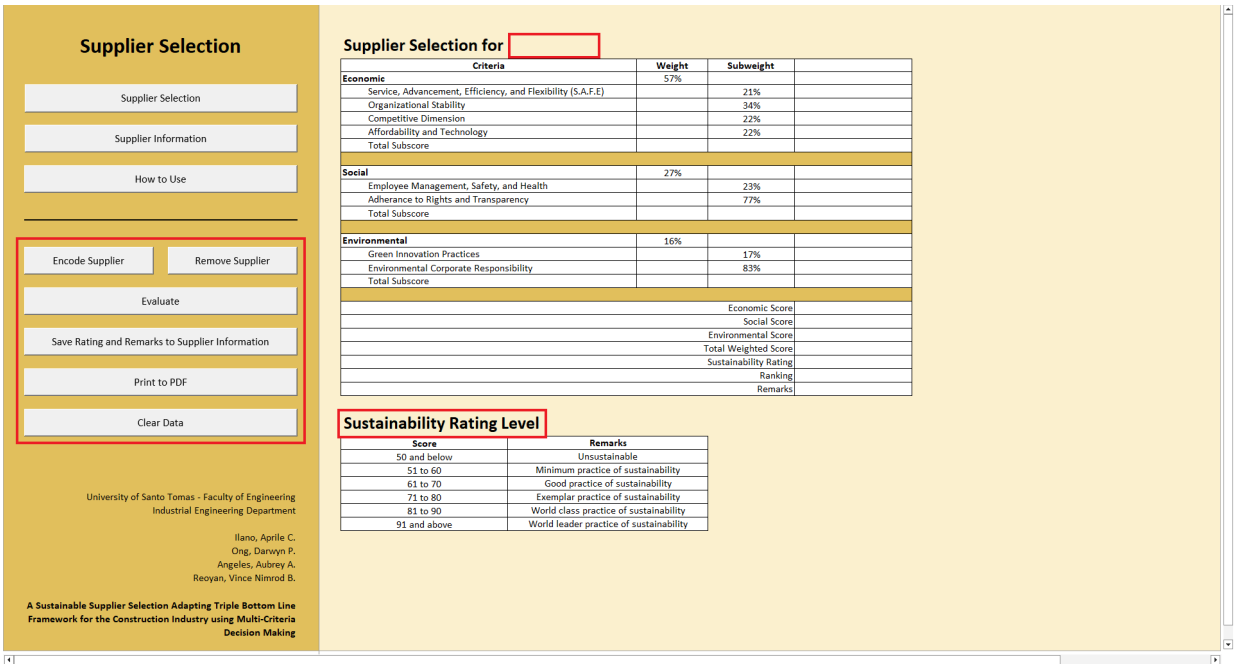

Figure 11. Supplier Selection Interface

The main command buttons on the Supplier Selection interface can also be found on the left side of the interface. The "Encode Supplier" button will prompt a user form that the user should fill up to input a material offered and the suppliers who will be evaluated. Only one material could be evaluated at a time. Thus, only the suppliers offering this specific material will appear on the company selection list. The user should encode the suppliers and their corresponding scores on each criterion one at a time. Once the form is complete and encoded, all information will appear in the interface. The "Remove Supplier" button will prompt a user form where the user can select the supplier that will be removed from the evaluation. The "Evaluate" button will compute the total score of each criterion and the weighted score concerning its relative importance, sustainability rating based on table 2, ranking, and give remarks whether to proceed or not on each supplier. The "Save Rating and Remarks to Supplier Information" button will copy the sustainability rating and remarks of each supplier to its corresponding row and remarks column on the supplier information interface. The "Print to PDF" button will enable the user to save the evaluation as PDF externally. A user form will be prompted where the user can enter the desired file name. The PDF file will be automatically saved in the computer's document folder. Lastly, the "Clear Data" button will reset the evaluation sheet. The encoded material offered, suppliers, scores, and results will be deleted.

6. Conclusions

The proponents used existing literatures and studies to determine different sub-criteria for each of the triple bottom line framework. 15 sub-criteria were found for the economic criterion, 10 sub-criteria for social criterion, and 12 sub-criteria for environmental criterion. Upon determining the sub-criteria, the data-gathering procedure was employed then factor analysis was utilized to determine the significant and insignificant criteria and sub-criteria and reduce the large number of variables into fewer number. The result of the hypothesis testing states that all main criteria and its sub-criteria have a significant impact on sustainable supplier selection in the Philippine construction industry. The environmental factor was reduced from 15 sub-criteria to four sub-criteria: S.A.F.E, Organizational Stability, Competitive Dimension, and Affordability and Technological Capability. The social factor was reduced from 10 sub-criteria to two sub-criteria: Employee Management, Safety and Health, and Adherence to Rights and Policy. Finally, the environmental factor was reduced from 12 sub-criteria to two sub-criteria: Green Innovation Practices and Environmental Corporate Social Responsibility. The proponents determined the relative weight of importance of the criteria and the synthesized sub-criteria through Analytical Hierarchy Process. The researchers developed a sustainable supplier selection tool using Excel VBA to aid procurement decision-makers in assessing the suppliers standing and addressing the growing negative impact of the construction industry on the economy, society, and the environment. In conclusion, the criteria and sub-criteria will serve as a guide in ensuring that the chosen supplier will benefit the company most, not solely by profit but also by social and environmental aspects.

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