MIVES Technique for Sustainability Assessment in Architecture and Civil Engineering Industries

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ABSTRACT

A subfield of computer science called artificial intelligence studies, develops, and uses intelligent computers. Massive computational resources are needed for complicated structure system modeling and optimization using traditional approaches; nevertheless, Artificial intelligence-driven solutions can often provide practical substitutes for efficiently addressing challenges in civil engineering. This paper presents a study that examines the merits and requirements of multidisciplinary collaboration between architecture and civil engineering students, focusing on the distinctions and overlaps in their aesthetic assessments and visual preferences. To illustrate the difficulties facing the Spanish Combined Value Model for Sustainability Assessment (MIVES), this research study synthesizes the different approaches for sustainability assessment for the construction industry and compares their advantages and disadvantages. The value function concept and expert seminars serve as the foundation for the Multi-Criteria Decision Making technique known as MIVES. Research indicates that the primary areas of interest for artificial intelligence studies in civil engineering are design optimization and structural maintenance and management. Finally, the primary research trends are also highlighted. An overview of artificial intelligence's advancements in civil engineering is given in this paper.

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1. INTRODUCTION

The first AI conference was conducted at Dartmouth University in 1956. AI is a broad field that includes computer science, control theory, linguistics, neurology, psychology, and philosophy. Artificial Intelligence, in its widest definition, is the capacity of a machine or other artifact to carry out tasks that a human mind can. The branch of computer science known as AI; is the driving force behind the development of intelligent machines or systems that exhibit characteristics of human intelligence, such as spoken language, understanding, comprehension, logic, problem-solving, and so on [1]. AI is generally acknowledged as a technology that provides a different approach to handling challenging and ill-defined issues. They have significant fault tolerance, which allows them to deal with incomplete and noisy data, the ability to learn from examples, and the ability to solve non-linear problems. Among other industries, AI has been applied in the domains of science, economics, medicine, and the military and marines. They have also been used in the management, prediction, identification, optimization, and modeling of complex systems.

The foundation of civil engineering is laid by important scientific discoveries. Theoretical techniques derived from basic sciences like physics, chemistry, and mathematics are used in the planning and constructing of engineering constructions and structures. Several review papers have been written about the advancements in these basic science fields and how they are used in building and construction, as well as civil engineering [2], throughout the past five years (2013–2017). There was a discussion of "inspired by nature" optimizations derived from chemistry, physics, and other natural sciences. As conceptual frameworks inspired by nature, we present the engineering uses for central force meta-heuristic optimization, simulated annealing, and gravity search algorithms.

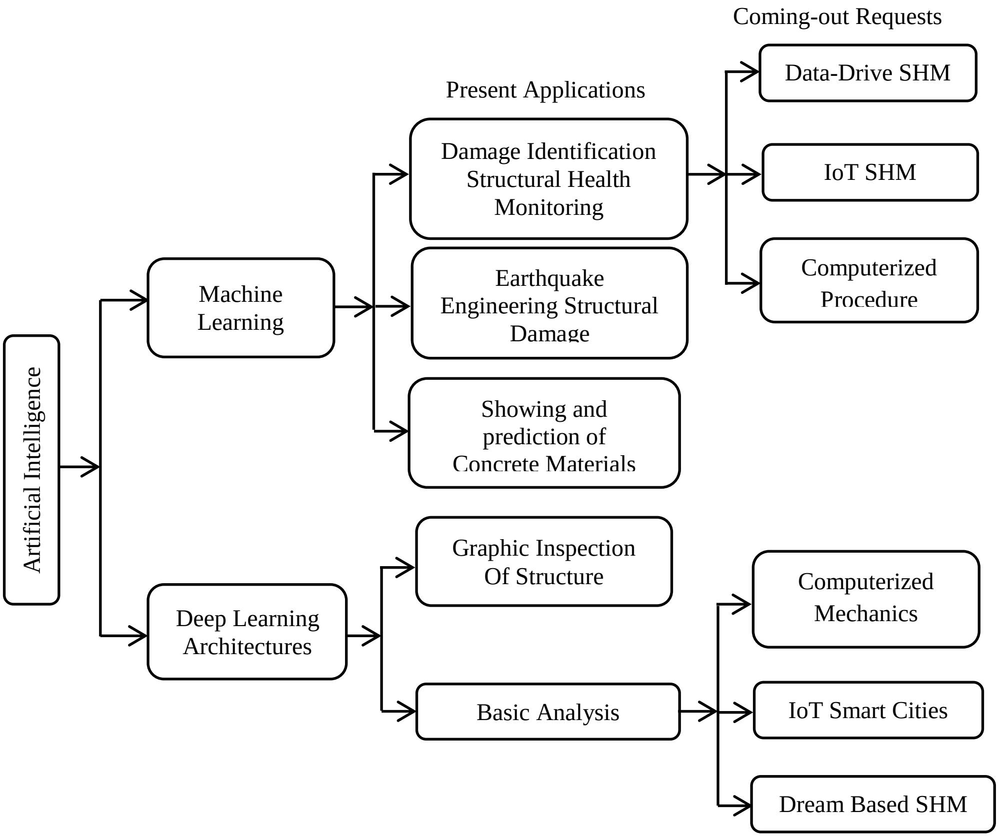

Figure 1.1 AI applications in several civil engineering domains

Figure 1.1 [3] illustrates the application of AI in different civil engineering domains. The artificial intelligence method is trained to represent the load-displacement connections that are used to determine the proper movement or stress reaction in the dynamic structural evaluation. The majority of typical causes of damage to a concrete structure include temperature fluctuations, cyclic loading, changes in loading circumstances, reinforcement corrosion, and natural hazards. Developing a structural health monitoring system is therefore the most crucial stage in identifying any deterioration in the current system. Through analysis, field investigation, and experimentation, it has been determined that these flaws in the structure cause changes in its inherent frequency ranges, dampening, dynamic reaction, and rigidity. These structural alterations make it easier to quantify and locate the building's damage and flaws.

In keeping with our evaluation of review papers, several review articles have been released that deal with particular difficulties in civil engineering and the use of information technology to help solve engineering problems. It was demonstrated how structural engineers might use support vector machines. This paper examines the use of artificial neural networks in neurocomputing for the optimization, monitoring, and control of civil infrastructure. An overview of the use of automation in construction activities and the integration of automated equipment into the building construction process is provided.

The remainder of the document is organized as follows: Section 2 covers the data collection process, including the databases from which the data is collected and analyzed; Sections 3 and 4 detail the outcomes of the technique used; Section 5 concludes the study and lists the authors.

2. LITERATURE REVIEW

Tan, K. et.al [4] In particular, material identification and optimization in the main uses of AI in the building sector. Initially, it will use a computer vision algorithm to assess the quantity and quality of the materials and examine their internal and external qualities. Second, the construction process will be adjusted and dynamically optimized through the use of artificial intelligence. If contradictions or conflicts arise throughout the building process, they will be resolved by examining the various construction sequences. AI can also assist decision-makers in developing models for decision-making, offering a range of options, and evaluating and comparing different plans to maximize benefits.

Diao, P. H., et.al [5] The configuration and properties of three-dimensional objects are often the subjects of study in architectural and civil engineering education, which is a type of practice-based knowledge delivery. It is common for component information, such as stress, dimensions, substances, assembly, and building, to be linked with a construction, like a building, bridge, or space. Construction documentation, concept, schematic, detailed, fabrication and assembly, and as-built designs have all been defined using building models. There has been a shift in the use of various simulations to online models for training, assessment, practice rehearsals, teaching, and solution presentations.

Jurado Mogrovejo, J. et.al [6] The conclusion structure known as the decision-making tree is defined by three tiers of aspects defined by MIVES: requirements, criteria, and indicators. First off, most of the time, the criteria align with the three sustainability dimensions. The factors that are contained in the decision framework and cannot be inspected right away are known as criteria. The metrics, which may be measured by matching each requirement, are the most exact part of the analytical structure. MIVES's homogeneity of metrics makes it possible to evaluate sustainability in all of its aspects.

Pujadas, P., et.al [7] The origins of multidimensional model classification can be found in the discriminant analysis of linear and quadratic forms. Other multi-criteria techniques have since been developed to provide a systematic framework for breaking down the problem into its constituent parts to comprehend it better and, in the end, come to a suitable evaluation. The cornerstone is the Integral Value Model for Architectural Evaluation for the multi-criteria method used in this work to assess the state of the urban pavement. Originally, the Multi-Criteria technique was created for the evaluation of sustainability.

Seraj, S., et.al [8] A significant proportion of natural aggregates are used in road construction. Research has shown that MSWI ash can be reused for road construction. Of the two options, BA is a better fit because of its physical attributes, while FA is viewed as a backup because it concentrates heavy metals and soluble salt. The results unequivocally show that utilizing waste on roads has benefits for the economy and ecology, including large cost savings, reductions in energy consumption, and emissions of carbon dioxide. Owing to the scope of the topic and the potency of the several components involved, an extensive assessment technique is needed.

Pons, O., et.al [9] After these centers were completed, The inquiry's schools' effects on the natural world were looked at. The use phase of these academic structures' life cycle was then shown to have a lower environmental impact than that of other building types. The surroundings of today are completely different: The global economic crisis is affecting not only the number of new-borns but also the migration patterns that have declined and will continue to do so, and there is a lower demand for school spaces. Thus, it's time to consider how to maximize upcoming educational buildings. As previously mentioned in the 1994 "International Council for Local Environmental Initiatives," the moment has come to promote equitable growth.

Manzoor, B., et.al [10] The architecture, engineering, and construction sector has always looked for ways to cut expenses, increase productivity, enhance sustainability, improve visualization, improve data sharing, decrease building waste, improve safety, raise quality, and improve sustainability—all while trying to shorten delivery times. To do business, the AEC sector still mainly relies on traditional designs and processes. At the same time, AEC professionals understand how valuable DTs are to attaining more accurate and intelligent modeling. Given the high profitability of the AEC industry, companies that effectively implement new technologies will be able to outperform their rivals as a result of their ability to do so. The AEC industry has only recently started the transition from convention to robotics, with enormous technology opportunities.

3. METHODS AND MATERIALS

3.1 Civil engineering characteristics that contribute to sustainability

The four main characteristics of civil engineering are originality, unpredictability, functionality, and interconnectedness.

3.1.1 Originality

The length of time needed to complete the task and the degree of involvement needed for the task are what often form the interconnectedness of construction projects. In addition, several workers are assigned, all at a uniform density, and connected in the construction sector; therefore complicated scheduling may provide challenges. The operation procedure should include several factors, including weather, security, operating hours, and time constraints [11]. Operations should be planned to take these factors into account to provide successful results efficiently. AI additionally aids in the computerization of important but laborious and repetitive tasks, freeing up human time and energy for higher-value job duties. Because of this, AI makes insights visible that would otherwise be hidden in enormous volumes of information sets that need to be managed and analyzed by humans. Examples of these data sets include data from tapes and photos, in addition to email messages, online posts, documents, and company papers.

3.1.2 Functionality

When a project begins, its initial scope and outcomes are determined. Nevertheless, the initial end goals become unclear if there are delays. Throughout a project, various needs arise for an array of reasons due to changes in conditions. To maintain equilibrium throughout the project's changing actuality, any changes in size, such as enlargement or reductions, must be matched by corresponding adjustments to the project's spending plan and timeline. Energy distribution and consumption optimization, together with the creation of automated sustainable development studies of items and regions are ongoing projects. Robotic automobiles that optimize driving behaviors and routes to reduce carbon emissions are also a topic of investigation. The design, manufacturing, and Before buying, the product establishes independent environmental goals, which are supplied by self-sufficient connections between an AI-enhanced good and its surroundings—including knowledge and decision-making—after buying it. On the other hand, before being purchased, construction, manufacturing, and transportation decide the static environmental advantages.

3.1.3 Unpredictability

Unknown hazards will always endanger the project's overall performance because they must typically be identified before they materialize. Interestingly, there is a high degree of uncertainty associated with large construction projects, which is directly tied to several aspects. Additionally, preparation and projection must be done before construction begins under a great deal of uncertainty; in particular, dates, timings, and costs are frequently vulnerable to alterations. There are still outstanding questions regarding the architecture design, such as whether or not it can pass audits and whether or not clients are satisfied. Additionally, if uncertainty is identified and assessed early on, possible risks may be minimized, increasing the possibility that a building project will be effective.

3.1.4 Interconnectedness

The intricate nature of managerial tasks arises as a result of the differences between building initiatives in terms of client demands, project scale, settings, impacts, and restrictions. It is insufficient to apply the same timetable, design scheme, finances, and strategy to a new project; as such, there is no need to try to apply budgets and plans from the previous project to the current one. Additionally, as an item or service can only be designed with design work and a working model, architects, designers, freelancers, and suppliers are necessary for every project. It indicates that every project is completed by a unique group of individuals and that each group has unique qualities, including aptitude, knowledge, expertise, and communication abilities.

3.2 The multi-criteria Analysis of MIVES

The MAUT MCDM technique known as MIVES was initially developed to assess sustainability in the construction sector. After that, it was changed to assess and prioritize both homogeneous and heterogeneous solutions. MIVES differs from previous MAUT MCDM systems in that it includes several components, including an allocation system, a gauge of values utility procedures, and a multi-level request-gathering framework. These components give MIVES a high degree of adaptability that may be tailored to any particular issue and offer logical, sustainability-based justification for the selection criteria.

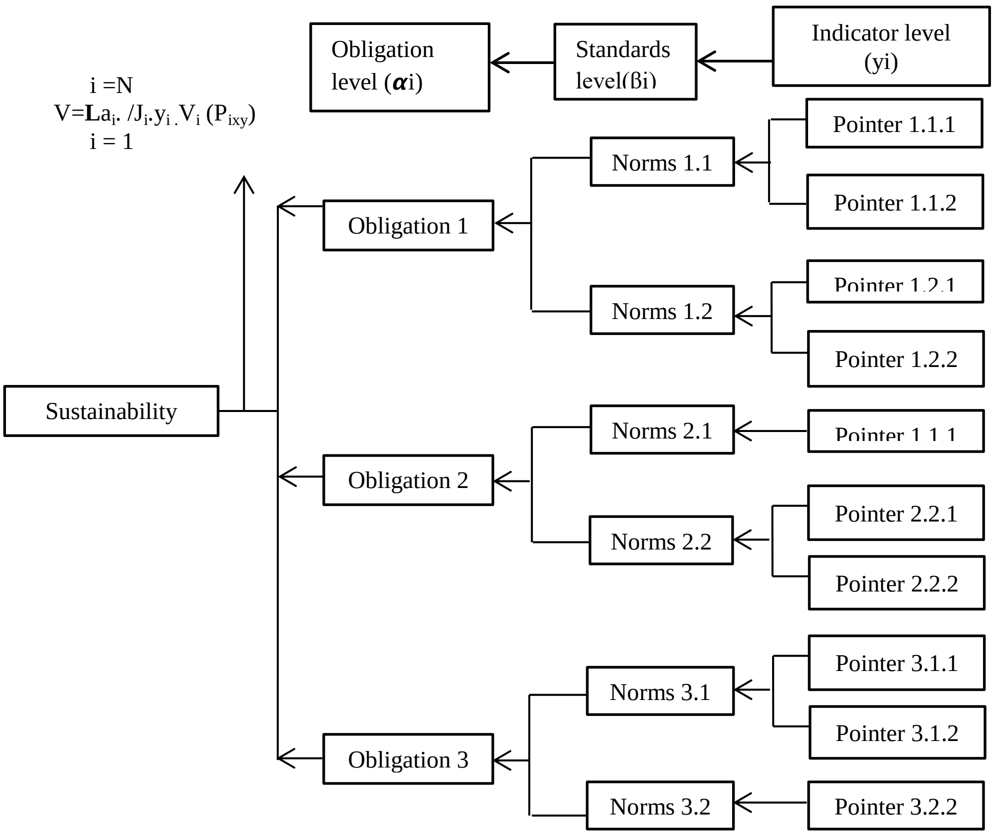

Figure 3.1 Overall Requirements Tree

The final viability index is obtained via a weight sum modeling method (see Figure 3.1) by aggregating these values using the provided weights following the utilization of value functionalities to obtain every indicator (or sub-indicator). To meet a predetermined sustainable aim [12], MIVES organizes the problem into a multi-criteria analysis framework that allows for the evaluation of many solutions based on a pre-established set of requirements. These prerequisites, which are often the problem's pillars of environmental, social, and financial sustainability, include a list of criteria. They also consist of a group of indications that could include sub-indicators, creating a multi-level computer called a choice tree.

Decision-makers employ procedures like the most popular MIVES method, the Analytic Hierarchy Process, to weigh each MIVES choice tree part differently to evaluate each component's relative value and conduct an issue analysis. First developed by Saty, the AHP is a linear addition model that creates a set of total scores or values based on pairwise comparisons from subjective assessments of their relative significance. Only the indicators are assessed, and depending on the indicator, several units and scales as well as quantitative or qualitative variables are used. After that, a value function is applied to the indicators to complete the assessment.

The value operation is a single calculation that creates a non-dimensional quantity with numbers between 0 and 1 from the two different types of variables that make up the indicators. Each type of variable has its scales and components. The lowest and highest level of fulfillment for the decision-maker is represented by these values.

4. IMPLEMENTATION AND EXPERIMENTAL RESULTS

As clarified in this Chapter, MIVES has been effectively utilized to examine sustainability in multiple building industry scenarios. A selection of examples that is representative of the energy, urban, edifices, and building technologies and components categories is shown in Table 1.

The variety of these cases—some dealing with architectural elements, others with energy or urban issues, some evaluating large samples generally, some doing in-depth analysis, etc.—demonstrates MIVES adaptability [13]. The references for each sustainability evaluation are included in this table.

Table 1. Various MIVES-based sustainability assessments conducted in the building Industry

Level	**Sustainability Valuation**
Liveliness	1. The sustainability index for support systems for wind turbines 2. Systems for producing electricity
Municipal	3. Sustainability site selection of Post-disaster interim housing in cities

	4. Evaluation of the sewerage pipe system's durability
Organizations	5. The sustainability of technologies for temporary housing complexes used after disasters 6. Sustainability evaluation of school construction technology 7. Commercial structure environmental analysis
Structure Systems and Elements	8. Evaluation of concrete structures for sustainability 9. The method of sustainability assessment used for structural concrete columns. 10. Evaluation of flooring made of concrete technologies for durability

These evaluations of sustainability each have unique characteristics. The detailed explanations of the particular research Cases 6 and 9 are provided in the following sections. These two examples illustrate the primary distinguishing features of MIVES and are indicative of the specifics of the many cases displayed in Table 1. While Case 9 examines a particular construction feature while taking into account all of its creative and structural properties, Case 6 evaluates a significant number of more than 400 educational buildings. They both adhere to the technique stages outlined, but as the sections that follow demonstrate, each case's requirement tree, measurements, and value algorithms are unique.

4.1 Applying Sustainable Evaluation to School Building Techniques

A further explanation of this evaluation tool's use can be found in the technical literature. This methodology was developed and applied to assess the future viability of more than 400 schools built in Spanish in the early 21st century. This tool was designed to analyze the tools and building processes utilized in the development of these educational buildings. These public kindergarten and primary schools, which served 200–400 kids, were built between 2000 and 2014 under strict financial constraints and in a short amount of time due to the urgent demand for new educational facilities.

These educational buildings were built with a variety of technology. The off-site concrete foundation structure technology (FC), off-site wood structure system (FT), off-site steel module structure system (FS), and off-site concrete building system (NC) were the most well-known ones. A few of their key attributes are shown in Table 2.

Table 2 Key attributes of the primary construction methods

	NC	**FC**	**FS**	**FT**
Organizational material	Concrete	Concrete	Steel	Timber
Organizational technology	Frames	Frames	Modules of frames	Load-bearing walls
Regular Building Speed (m^2/month)	151	251	251	251
Average distance factory-site (km)	86	151	901	1601
Average weight (kg/m^2)	1465	947	409	508
Support required	High	Low	None	Low
Disassembly possibilities	None	Low	High	High

The worldwide and partial sustainable indices for the construction options were the primary outcomes of this assessment. The evaluated technologies could be categorized using the global indices from more sustainable to less sustainable, and the partial indexes helped advise the respective industries on how to get better. The respective global indexes for NC, FC, FS, and FT were 0.35, 0.72, 0.71, and 0.59, respectively. For example, despite being a high-performance ecological construction system, the examined timber technology had a surprisingly low sustainability index.

4.2 Method of Sustainability Assessment Used for Structural Concrete Columns

Table 3. Column substitutes evaluated in this research scenario

Alternative	**C.Ch. Strength (N/mm^2)**	**Cross-Section (cm)**	**Construction Process**
Round 1 Round 2	25	ϕ 30	S-C V
Round 3 Round 4	50	ϕ 35	S-C V
Round 5 Round 6	75	ϕ 50	S-C V
Four-sided 1 Four-sided 2	25	$25x25$	S-C V

Fair 3 Fair 4	50	30 *x*30	S-C V
Fair 5 Fair 6	75	40 *x*40	S-C V

This environmentally friendly tool has been used to examine substitutes that make use of high-strength, self-compacting, and quick-hardening concretes. These modern concrete allow for the construction of columns with greater load capacities and lower cross sections. As a result, they enable the building to use less material, have fewer columns, and maximize the amount of available building space. In addition to improving job performance, these concrete allow for quicker building times. As a result, several social impact aspects are diminished, including noise from buildings and the need for specialized modes of mobility.

For medium-sized buildings with up to six stories and 500 square meters per floor, This instrument has already been used to evaluate the viability of several alternatives for in situ reinforced concrete columns. The examination focuses on the building's third and fourth-level columns. The 3 m high pillars are grouped into a 6 m by 6 m skeletal net. They don't have an excessive reinforcement ratio because of bending loads, and their compression stresses are primarily moderate. Unknowns like building problems and original issues have been considered, though. As advised by Model Code 2010, a minimal eccentricity of a value of h/30, where h is the greatest cross-section dimension, has been taken into consideration to accomplish this. The cross-sectional forms and dimensions, compressive properties of the concrete, and construction methods of these alternatives vary. The MIVES tool has also looked at how these variables affect the assessed choices' environmental sustainability scores, which are displayed in Table 3 (see Figure 4.1). Table 4 shows the measurements, the value function forms, and the specifications tree for this instrument.

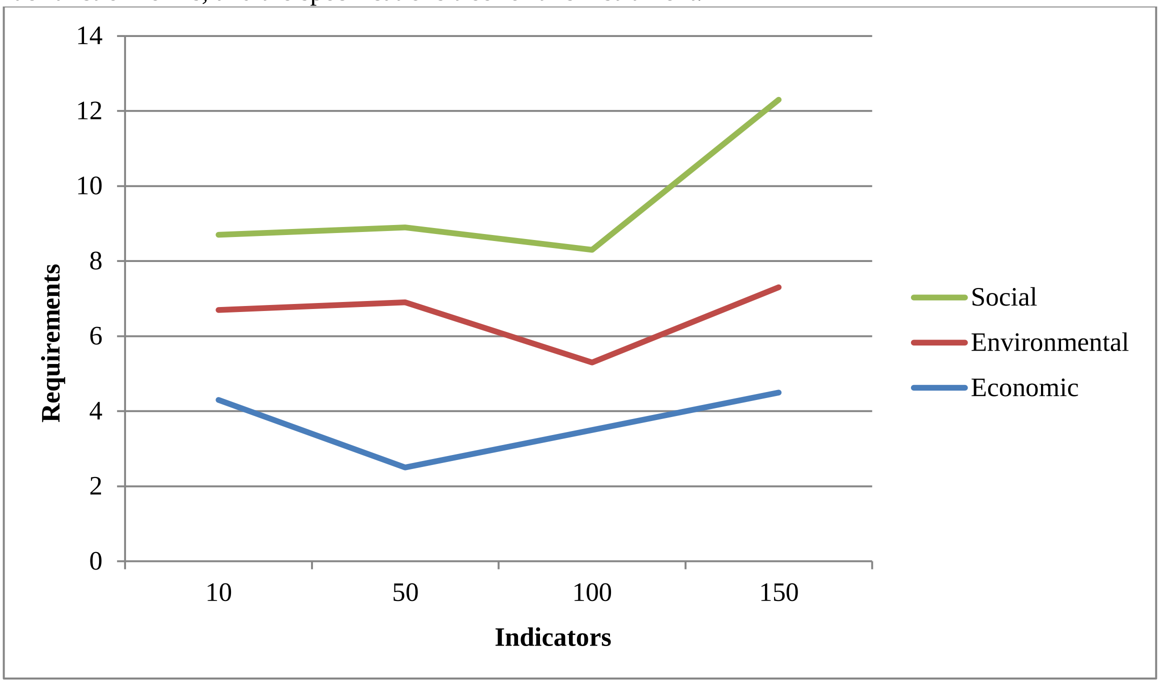

Figure 4.1. The primary building technology

Table 4. Requirements Tree, weights and vale functions shapes for structural concrete columns

Requirements	Criteria	Indicators
R1.Economic (50%)	C1. Construction Costs (67%)	11.Building costs (85%,DS) 12.Non acceptance cost (15%,IL)
	C2. Efficiency (33%)	13.Maintenance (60%,Ds) 14. Habitability (40%,DCv)
R2. Environmental (33%)	C3. Emissions (67%)	15. CO_2 emissions (100%, DS)
	C4. Resources consumption (33%)	16.Concrete Consumption (90%,DCv) 17.Steel consumption (10%, DCx)
R3. Social (17%)	C5. Negative effects on the producer industry (80%)	18.Workers' inconveniences (20%,DS) 19. Workers' safety (80%,IL)
	C6. Effects to third party (20%)	110. Environment nuisances (100%,IL)

This examination led us to the conclusion that the most sustainable constructions are those composed of concrete with a high typical compressive stiffness and columns with smaller cross sections. This is the replacement Circular 1, with a global sustainability index of 0.85. The following conclusions were reached after analyzing the previously mentioned variables: circular sections are healthier than square or rectangular ones for both functional and aesthetic reasons; circular rows have a higher index when using durable concrete and have smaller cross-section areas; square and rectangular alternatives have larger sections and require vibration; and self-compacting concrete materials have a higher environmental sustainability index than those that require vibration.

MIVES can produce practical sustainability evaluation tools for a variety of building-related scenarios. It can define comprehensive tools for certain samples and research cases, as demonstrated in earlier sections. The MIVES application's applicability has been evaluated in a few of these instances, and the MCDM has shown to be the most effective long-term instrument for those investigations. The primary sources of MIVES's weaknesses stem from this approach. These disadvantages include the time and effort required by specialists to define each specialised evaluation instrument in accordance with the previously specified procedures.

These shortcomings can be addressed with excellent outcomes, as demonstrated by the narrowly defined scenarios where MIVES has previously been used. Their findings demonstrate that these flaws just make the entire process more challenging; they have no bearing on the final tool or its long-term evaluation. Therefore, the basis for addressing these shortcomings is strengthening the seven elements of this methodology procedure before utilising the evaluation instrument. However, these disadvantages will make it impractical to use this MCDM in specific assessment scenarios. Lastly, no alternative instruments have been discovered that could be utilized to complete the evaluation in other situations not included in the preceding paragraphs.

5. CONCLUSIONS

The process of assessing sustainability performance is intricate and fraught with uncertainty concerning the assessment and management of the indicators, this research provided a multi-criterion, MIVES-based approach to assess the environmental sustainability index of facade panels, accounting for social, environmental, and economic aspects. The approach was applied to newly manufactured cement boards derived from textile waste (TW). Furthermore, an experimental program was carried out as part of this investigation to describe the thermal, acoustic, and combustibility of this substance; the results were integrated into the evaluation of the sustainability model.

It was discovered that AI can enhance and expedite learning, which is beneficial for building projects with varying fundamental features. Our living conditions have greatly improved as a result of creativity and technology. Innovation and technological advancement will also play a key role in the shift to a more sustainable future. AI and other productivity-boosting digital technologies can help boost output, lower production costs, and emission levels, lessen the intensity of resources used in the manufacturing process, improve market alignment, and make it possible to leverage big data to improve public services accessibility.

In this study article, a full analysis of MIVES has been carried out. This approach has been thoroughly examined through the presentation and discussion of its phases, application domain, and two case studies. The investigation shows that for the majority of samples in the construction industry, MIVES can establish comprehensive, objective, and simple-to-use sustainability evaluation techniques. These techniques evaluate homogenous or diverse alternatives, are case-specific, might be probabilistic or deterministic, and provide comprehensive sustainability indices. As such, MIVES cannot be used for urgent assessments that require the use of a new, specialized tool. This constraint is typical of newly used technologies that require a definition process before the evaluation. However, as demonstrated in earlier sections, this limitation has previously been solved in several MIVES study cases by anticipating the procedure of creating each new tool.

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