

Sustainable Construction Engineering and Management

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Abstract: The Special Issue covers sustainability as an emerging requirement in the fields of construction management, project management and engineering. We invited authors to submit their theoretical or experimental research articles that address the challenges and opportunities for sustainable construction in all its facets, including technical topics and specific operational or procedural solutions, as well as strategic approaches aimed at the project, company or industry level. Central to developments are smart technologies and sophisticated decision-making mechanisms that augment sustainable outcomes. The Special Issue was received with great interest by the research community and attracted a high number of submissions. The selection process sought to balance the inclusion of a broad representative spread of topics against research quality, with editors and reviewers settling on thirty-three articles for publication. The Guest Editors invite all participating researchers and those interested in sustainable construction engineering and management to read this summary of the Special Issue and of course to access the full-text articles for deeper analyses.

Keywords: sustainability; construction management; project management; design; materials; maintenance; smart technologies; decision-making methods



Citation: Zavadskas, E.K.; Antucheviciene, J.; Hosseini, M.R.; Martek, I. Sustainable Construction Engineering and Management. *Sustainability* **2021**, *13*, 13028. <https://doi.org/10.3390/su132313028>

Received: 17 November 2021
Accepted: 22 November 2021
Published: 25 November 2021

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1. Introduction

The 20th century was an age of unprecedented growth in the use of natural resources and materials. Global demand for materials grew during that century, following the steady economic growth in OECD—Organization for Economic Co-operation and Development—countries, the industrialization of emerging economies and a growing world population [1,2]. At the global level, the extraction of raw materials more than doubled between 1990 and 2017 and is projected to double again by 2060. These recent trends, however, will not be enough to counteract the rising demands and ongoing quest for higher living standards of a world population headed to more than 10 billion by 2060, of whom more than 75% are expected to live in urban areas [3].

Three socio-economic factors generally drive the use of materials and resources. First, a growing global population and the progressive convergence in living standards across countries lead to higher consumption, thus increasing materials use. Furthermore, as economies develop, investments in construction and infrastructure increase, leading to a higher demand for materials [4,5]. Second, technological improvements reduce energy consumption, which can decrease the material intensity of production [1], thus reducing the materials input required to produce a given economic good. For instance, prefabrication, as an advanced construction technology, is more resource-efficient (requiring less material and generating less waste) and performs better economically than previous methods [6,7]. Third, with structural changes in the landscape of the overarching economy, the material intensity of the economy can be further reduced. As specified in a recent OECD report, as income levels rise, aggregate demand shifts towards less resource-intensive sectors, such

as services and leisure activities [2]. Overall, technological advancements and structural changes have the potential to counterbalance the increasing demand for materials use, partially decoupling materials use from economic growth [7,8].

In recent years, countries have demonstrated a stronger interest in resource efficiency, not only to address environmental issues but also to achieve objectives such as economic growth as well as employment and resource security [9]. Sustainability is currently more than a fad or fashion that engineers and construction managers can choose to embrace if they wish or ignore if they prefer to focus on traditional core competencies. It has become a moral imperative, a global political priority [10]. It is the benchmark by which ‘good, socially responsible’ companies are measured and given a pass or fail. Engineering and construction firms can no longer afford to ignore the call to take up the ‘sustainability cause,’ lest they become ostracized and labeled irresponsible.

If that view seems extreme, consider current developments. The Gudamalulgal indigenous community that inhabit the Boigu and Saibai islands of the Torres Strait, Northern Australia have brought a High Court case against the Australian Federal Government, claiming that Australian inaction is causing ‘catastrophic climate change’ that threatens the livelihoods of the island people [11]. This is despite the fact that Australia’s contribution to world CO₂ emissions is only 1% of the world’s total [12]. The point is that adopting a disinterested or neutral position regarding activist community demands in relation to sustainability concerns is no longer possible.

The challenge is not limited to the political arena but has bled into corporate activities as well. A Netherlands court has ruled that the global conglomerate, Royal Dutch Shell, must reduce its carbon emissions by 45% by 2030. The ruling applies not only to the company itself but to suppliers and ominously to emissions generated by all its customers worldwide. The court’s judgment can be expected to set a precedent—and a warning—to companies everywhere, that they must fall in line in addressing sustainability and in mitigating climate change. Sara Shaw, a spokesperson for ‘Friends of the Earth International’ commented, “Our hope is that this verdict will trigger a wave of climate litigation against big polluters.” [13].

The biggest polluters are in fact the construction industry [14]. Globally, the built environment eats up a full one-third of all the world’s raw materials. Specifically, the fabrication of buildings consumes one-sixth of all freshwater, one-third of all timber, and four-fifths of everything else. Buildings, too, are the biggest users of energy. One-tenth of the world’s energy goes into making building materials. Then, just to keep the lights on and heating running, buildings absorb a full one-half of all the energy generated in the world [15,16]. Nothing comes close to impacting the planet more adversely than the construction industry does, and attention is being drawn to this uncomfortable fact.

Firms operating in the construction sector are increasingly well aware of their impact. Many, however, have found it difficult to respond. For one, the construction industry is notoriously bad at innovation, particularly when it comes to matters of improving materials, waste and energy efficiencies [4,17]. Second, becoming sustainable is expensive—up to double the cost—and few business models in the sector have managed to identify who it is that would gladly pay for more expensive, ‘green buildings;’ most clients would certainly not.

Multiple-criteria decision-making (MCDM) methods can be helpful in resolving the contradictory aims of politics and industry. They are especially valuable in identifying compromise solutions in the area of sustainability, including sustainability engineering [18], civil engineering, construction and building technology [19,20]. The most frequently used hybrid decision-making methods harness the advantages of hybrid approaches over individual methods, and they can assist decision-makers in handling information such as stakeholders’ preferences, interconnected or contradictory criteria, and uncertain environments [21]. A variety of fuzzy multiple-criteria decision-making models have been proposed to solve complicated decision-making problems. Many fuzzy MCDM applications have been utilized in the field of civil engineering and management [22],

including in construction project selection [23], construction safety risk assessment [24] and supplier selection [25].

Ultimately, one question remains: What practical measures can industry practitioners adopt that meaningfully embrace the sustainability agenda and improve the industry's performance?

The Special Issue on 'sustainability as an emerging requirement in the fields of construction management, project management and engineering' is an effort to answer that question. Experts in their various capacities were invited to comment and report on the latest innovations and breakthroughs being made in the construction industry that would make it more sustainable. Their many insightful contributions are reported here—some 33 papers. Interested readers are invited to review the titles summarized in Table 1 and to download and examine those papers that hold a particular interest for them. They are, of course, all worth a close read.

Table 1. Contributions by research areas and applied solution methods/technologies.

Contributions	Research Area/Object	Applied/Developed Solution Methods/Technologies
Contribution 1	Risk management in infrastructure projects	IDEFO (Integration Definition for Function Modeling)
Contribution 2	Management and evaluation of construction projects	AHP (Analytic Hierarchy Process), Decision Tree
Contribution 3	Digitalization of construction	Review paper
Contribution 4	Evaluation of life cycle of residential buildings	Environmental impact in terms of CO ₂ emissions, etc.
Contribution 5	Infrastructure maintenance, decision-making	Optimization
Contribution 6	PPP sustainability, critical success factors	Fuzzy synthetic evaluation
Contribution 7	Fly ash geopolymer in construction industry	COLA (Cross-organizational approach), systematic literature review
Contribution 8	Highway construction projects	Triangular intuitionistic fuzzy decision-making
Contribution 9	Selection of building insulation materials	Systematic literature review of MCDM applications
Contribution 10	Public construction; data auto correction system	Machine learning, natural data processing
Contribution 11	Modernization of construction industry, organizational innovation, enterprise competitiveness	SEM (Structural Equation Modeling)
Contribution 12	Ranking of green materials	SWARA (Stepwise Weight Assessment Ratio Analysis), COPRAS (Complex Proportional Assessment)
Contribution 13	Building projects' sustainable value management in developing countries	EFA (Exploratory Factor Analysis)
Contribution 14	Reworks of building construction projects	SWARA, BIM (Building Information Modeling)
Contribution 15	Construction project scheduling	Resource constrained critical path method
Contribution 16	Construction management	Last Planner System
Contribution 17	Probabilistic structural design	Sensitivity analysis, uncertainty modeling, stochastic simulation
Contribution 18	Bridge construction, risk assessment	Loss assessment model
Contribution 19	Risk delay in construction projects	Artificial intelligence, random forest genetic algorithm
Contribution 20	Green buildings, LEED (Leadership in Energy and Environmental Design) credits	Analysis of LEED certificated projects
Contribution 21	Integrated design process of modular construction	DS/m (Dependency Structure Matrix) process optimization
Contribution 22	Roof installation projects	AHP (Analytic Hierarchy Process), Decision Tree
Contribution 23	Defect management in residential buildings	LDA (Loss Distribution Approach)
Contribution 24	Facility management	BIM, BPA (Building Performance Assessment), KPIS (Key Performance Indicators), etc.

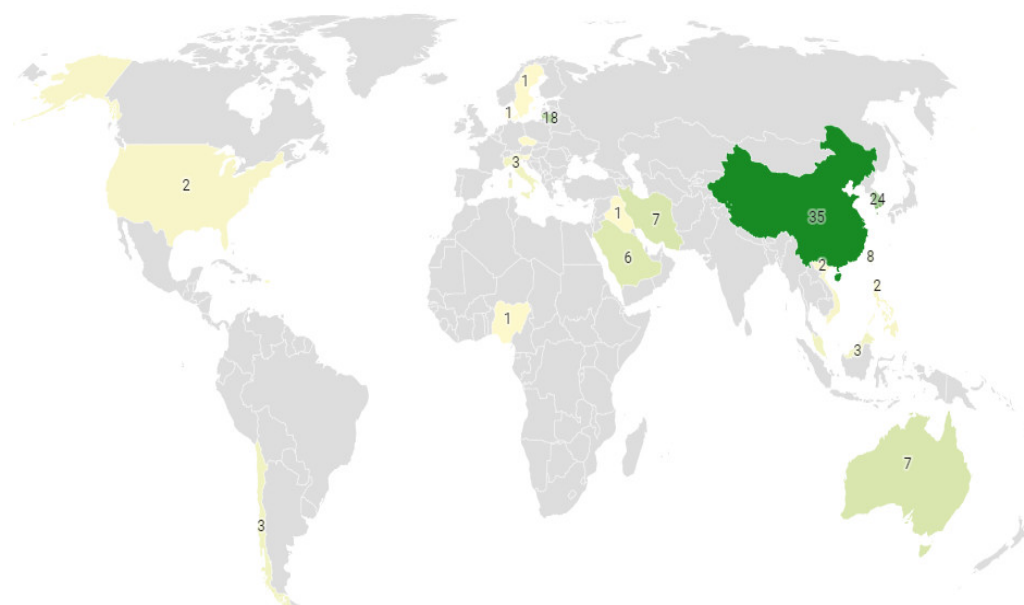
Table 1. Cont.

Contributions	Research Area/Object	Applied/Developed Solution Methods/Technologies
Contribution 25	Safety knowledge transfer in construction industry	SEM (Structural Equation Modeling)
Contribution 26	Power construction projects	Time management, delay management, expert survey
Contribution 27	Metro line project management	Set pair analysis
Contribution 28	Bridge deterioration prediction	Semi-Markov process, Weibull distribution
Contribution 29	LEED certificated projects; challenges for general contractor	Review of projects, expert survey
Contribution 30	Concrete temperature monitoring in high-rise building constructions	WSN (Wireless sensor network)
Contribution 31	Risks in construction PPP (Public-private partnership) projects	Integrated FISIM (fuzzy interpretative structural modelling)-MICMAC (matrix impact cross-reference multiplication applied to a classification) approach, triangular fuzzy numbers
Contribution 32	Bridge management system based on BIM	BIM, IFC (Industry Foundation Classes), IFD (International Framework for Dictionaries)
Contribution 33	Sustainable project management	BIM, TAM (Technology Acceptance Model), TOE (Technology-Organization-Environment), SEM

2. Contributions

After careful evaluation, thirty-three papers were accepted and published in the Special Issue.

The Special Issue raised the interest of researchers from various scientific schools all over the world. Submissions came in from Europe, Asia, North and South America, Australia, and Africa. One hundred and twenty-five researchers from nineteen different countries contributed to the published papers (Figure 1). The greatest number of submissions came from Asia (China and Korea) followed by Lithuania. There was a strong representation comprising of six to eight authors from Taiwan, Australia, Iran and Saudi Arabia. The remaining countries fielded between one to three authors.



Though authors from nineteen countries contributed to the Special Issue, national research collectives dominated. Almost two-thirds of the publications were authored by researchers from one country (twenty-one papers). Twelve papers were prepared by international co-authors' collectives, usually consisting of researchers from two or three countries.

The authors proposed various solution methods or advanced technologies in order to deal with matters that addressed sustainable development in construction engineering or management (Table 1).

Several papers proposed different multiple-criteria decision-making models (Contributions 2, 12, 14, 22 and 31), often dealing with uncertain data and applying fuzzy modeling (Contributions 6, 8 and 31). Other papers analyzed the application of modern construction digitalization techniques in terms of BIM (Building Information Modeling) (Contributions 3, 14, 24, 32 and 33), artificial intelligence (Contribution 19) and wireless sensors (Contribution 30). Two papers performed expert surveys and analyzed the results (Contributions 26 and 29), and three papers undertook systematic literature reviews of their research areas (Contributions 3, 7 and 9).

The application fields of the proposed/applied solution models or technologies involved different civil engineering and management problems, including risk management (Contributions 1, 18, 19 and 31), life cycle management (Contribution 4), key performance indicators (Contributions 6 and 24), value management (Contribution 13) and loss assessment (Contributions 18 and 23), project scheduling (Contribution 15), time and delay management (Contribution 26) and reworks (Contribution 14). Two papers analyzed the LEED building certification system (Contributions 20 and 29). One paper (Contribution 16) was focused on the Last planner system.

The construction object forms that were analyzed comprised a very wide range, including residential buildings (Contributions 5 and 33), public construction (Contribution 10), various infrastructure objects (Contributions 1 and 5) such as highways (Contribution 8), metro lines (Contribution 27) and bridges (Contributions 18, 28 and 32), power constructions (Contribution 26), as well as high-rise buildings (Contribution 30). Some of the papers analysed construction materials' performance or their selection (Contributions 7, 9 and 12). Several others considered the managerial aspects of construction enterprises or public-private partnerships (Contributions 6, 11 and 31).

3. Conclusions

'Sustainability' is at once a new concept but one with a long history. Its meaning has evolved over time. The premise that humankind can impact the planet on which we live can be said to originate with God's command to Adam and Eve to 'go forth and subdue the Earth'. A zeal to exploit the globe's riches of gold, spices and materials is what drove the great colonial expansions of the 15th through 18th centuries. Then, in 1798, the mathematician Robert Malthus warned that exponential population growth was soon going to collide with the hard reality that the Earth's resources were both finite and depleting. In the mid-20th century, we became concerned with rising pollution, then old-growth forest decimation, then acid rain, and then the disintegration of the ozone layer. Through the 1970s, the problem was not that we were using fossil fuels too much but that there were not enough petroleum reserves to keep cars moving and the lights on into the next generation. More recently, the problem has metamorphosed into the familiar rally to fight 'global warming.' We were warned that temperatures would rise, rains would cease and that water resources would dry up. As it turns out, we are getting the rain, so now the preferred euphemism is 'climate change' [16,26].

While the perceived nature of the threat to our planet has shifted over time and will no doubt shift again, the fact remains that the global community is crying out for action. Thus, such concerns—no matter whether real or uncertain—must be responded to and met. As noted in the introduction, the construction industry is the one global sector with a massively disproportionate negative impact on the environment and on people. Architects, engineers, builders and project managers have no alternative but to take up

the sustainability cause. The excuse according to which the way forward is unknown and uncharted is no longer valid. Society expects the industry to shift. The list of readings provided here is an enlightened and refreshingly optimistic collection of strategies for bringing the construction industry into the 21st century of socially responsible engineering and building.

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2. Maceika, A.; Bugajev, A.; Šostak, O.R.; Vilotienė, T. Decision Tree and AHP Methods Application for Projects Assessment: A Case Study.
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Author Contributions: All authors contributed equally to this work. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Data sharing not applicable.

Acknowledgments: Authors express their gratitude to the journal *Sustainability*.

Conflicts of Interest: The authors declare no conflict of interest.

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