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Editorial

Sustainability and Resilience of Engineering Assets

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Abstract: The frequency and severity of natural or human-induced disaster events, such as floods, earthquakes, hurricanes, fires, pandemics, hazardous material spills, groundwater contamination, structural failures, explosions, etc., as well as their impacts, have greatly increased in recent decades due to population growth and extensive urbanization, among other factors. The World Bank estimates that the total cost of cities' and communities' vulnerability to these types of disasters could reach more than USD 300 billion per year by 2030. However, it has been argued that investment to improve the quality and resilience of engineered physical assets that are the backbone of modern societies, such as critical infrastructure, industrial facilities, and buildings, could significantly contribute to more sustainable and prosperous societies. Engineered assets are key to the delivery of essential services, such as transport, food, water, electricity supply, health and safety, etc. Some of these physical assets are integrated into asset systems and national or regional networks, with life cycles of several decades or even centuries. It is, therefore, of great importance that strategies and life cycle decisions, such as those related to short- and long-term capital investment planning, maintenance strategies, operational plans, and asset disposal, lead to the maximization of the value derived from these assets. Moreover, it is essential that the achievement of these goals is sustainable over time. Organizations dealing with engineering assets, both public and private, must, therefore, integrate sustainability and resilience concerns into everyday operations, using budgets that are often restricted, while also meeting demanding performance requirements in risky and uncertain environments. This Special Issue collates a selection of papers reporting the latest research and case studies regarding the trends and emerging strategies used to address these challenges, with contributions discussing how asset management principles and techniques can help to push the boundaries of sophistication and innovation to improve the life cycle management of engineered assets to ensure more sustainable and resilient cities and societies.

Keywords: engineering asset management; sustainable development; resilience; life cycle management; decision making; critical infrastructures; industrial facilities; buildings and built environment; digital transformation; regulations and policy; innovation; emerging risks; disaster risk reduction; management systems

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This Editorial provides an overview of this Special Issue, which focuses on critical engineering assets and systems. Its aim is to contribute to the discussion of sustainability and resilience in urban environments [1,2], which has gained increased importance in the last decade [3,4]. This Special Issue is organized into three major groups of contributions, as listed in Figure 1, with each exploring different facets of asset management in the context of urban infrastructure [5].

This Special Issue includes 11 contributions that collectively offer insights into the actions and strategies used for strengthening the resilience and sustainability of modern societies. These actions and strategies are examined as follows (see Figure 1): (i) at the level of inter-related infrastructure serving communities and cities; (ii) at the level of specific national, regional, or local asset networks or asset systems; (iii) from a cross-disciplinary standpoint, with an emphasis on innovative approaches used to improve asset value realization.

1. Analysis of inter-related urban asset systems
- *1.1. Multi-municipality urban infrastructure*
  - *i. A Systematic Literature Review on Urban Resilience Enabled with Asset and Disaster Risk Management Approaches and GIS-Based Decision Support Tools*
  - *ii. Measuring Urban Infrastructure Resilience via Pressure-State-Response Framework in Four Chinese Municipalities*
- *1.2. Single-municipality critical infrastructure*
  - *iii. Spatial Vulnerability Assessment of Critical Infrastructure Based on Fire Risk through GIS Systems—Case Study: Historic City Center of Guimarães, Portugal*

2. Analysis of asset networks and asset systems
- *2.1. Building portfolios*
  - *iv. Risk and Resilience Assessment of Lisbon's School Buildings Based on Seismic Scenarios*
  - *v. A Sustainability Analysis Based on the LCA–Energy–Carbon Emission Approach in the Building System*
- *2.2. Transportation networks*
  - *vi. A Novel Approach for Modeling and Evaluating Road Operational Resilience Based on Pressure-State-Response Theory and Dynamic Bayesian Networks*
  - *vii. A Systematic Review: To Increase Transportation Infrastructure Resilience to Flooding Events*
  - *viii. Fragility Analysis Based on Damaged Bridges during the 2021 Flood in Germany*
- *2.3. Power generation infrastructure*
  - *ix. Generating More Hydroelecticity While Ensuring the Safety: Resilience Assessment Study for Bukhangang Watershed in South Korea*

3. Analysis of innovative approaches to improve asset value realization
- *3.1. Digitalization and information asset management*
  - *x. Operation Principles of the Industrial Facility Infrastructures Using Building Information Modeling (BIM) Technology in Conjunction with Model-Based System Engineering (MBSE)*
- *3.2. Sustainable and innovative materials*
  - *xi. A Quantitative Group Decision-Making Methodology for Structural Eco-Materials Selection Based on Qualitative Sustainability Attributes*

Figure 1. Organization of this Special Issue.

In the first group of contributions, the authors explore the dynamics of inter-related urban asset systems. The three contributions included in this group emphasize the pivotal roles of employing asset and disaster risk management, emergency planning, and proactive preparedness strategies to enhance resilience. This group of contributions includes investigations into both multi- and single-municipality urban infrastructure, namely a systematic literature review of the contemporary urban resilience literature, advocating for the integration of asset and disaster risk management [6] with GIS-based decision support tools, as well as two other studies offering insights into urban infrastructure resilience measurement techniques in Chinese municipalities, on one hand, and strategies for dealing with fire risks in the historic city center of Guimarães, Portugal, on the other hand.

The second group of contributions focuses on specific sustainability- and resilience-related approaches used for specific types of asset networks and asset systems. It includes advances from previous studies examining the resilience of public-school building portfolios [7] in the face of seismic risks in the Portuguese capital Lisbon, discussing the practical implications of resilient urban planning in terms of emergency response and asset management strategies. Another study approaches building asset systems by seeking to combine sustainability and resilience, as it explores the role of renewable energy systems in the entire life cycle of the building asset system [8] in the face of varying energy consumption needs and carbon emission patterns.

The second group also includes three studies exploring issues related to transportation networks [9]. One of them discusses an innovative framework employing Pressure-State-Response theory and Dynamic Bayesian Networks to capture multidimensional factors influencing roads' operational resilience. Another study conducts a systematic review, covering literature dating from 1900 to 2021, presenting actions and gaps to increase transportation infrastructure's resilience to flooding events [10]. Finally, a third study dealing with transportation networks evaluates bridge resilience in the face of the damage inflicted during the 2021 flood in Germany.

The second group also includes a study located within the domain of power generation infrastructure [11], which attests to the ongoing efforts in the energy sector to harmonize production with infrastructure safety, further emphasizing the need for sustainable and resilient power systems [12].

Finally, the third group of contributions presents examples of innovative strategies and trends in asset management in view of the optimum value realization [13]. One of these contributions delves into digitalization and information asset management [14], adding value to the ongoing discussions about the operation principles of industrial facility infrastructure and the implications of using Building Information Modeling (BIM) technology to enhance digital asset management [15]. The other study presents a decision-making methodology for selecting structural eco-materials [16], offering a systematic and quantifiable framework for evaluating materials through the lens of sustainability. This latter study stresses the importance of alignment with the Sustainable Development Goals and provides some guidance for builders, architects, regulators, and investors in this regard.

Collectively, these studies show that engineering asset management requires a holistic and transdisciplinary approach when addressing the complexities of enhancing the sustainability and resilience of cities and communities [17–19]. The thematic focus is relevant to policymakers, industry practitioners, and the academic and research communities. This Special Issue′s pertinence is heightened amid escalating natural and man-made hazards, as it helps to deepen the theoretical discourse and shows examples of actions and strategies that can contribute to creating a more resilient and sustainable urban environment.

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References

1. Kapucu, N.; Ge, Y. 'Gurt'; Martín, Y.; Williamson, Z. Urban Resilience for Building a Sustainable and Safe Environment. *Urban Gov.* **2021**, *1*, 10–16. [CrossRef]
2. Meerow, S.; Newell, J.P.; Stults, M. Defining Urban Resilience: A Review. *Landsc. Urban Plan* **2016**, *147*, 38–49. [CrossRef]
3. Olsson, P.; Galaz, V.; Boonstra, W.J. Sustainability Transformations: A Resilience Perspective. *Ecol. Soc.* **2014**, *19*, 1. [CrossRef]
4. Elmqvist, T. Development: Sustainability and Resilience Differ. *Nature* **2017**, *546*, 352. [CrossRef] [PubMed]
5. Almeida, N. Fundamentos e perspetivas de inovação na gestão de ativos de engenharia. *Rev. De Ativos De Eng.* **2023**, *1*, 5–16. [CrossRef]
6. Rezvani, S.M.H.S.; Falcão, M.J.; Komljenovic, D.; de Almeida, N.M. A Systematic Literature Review on Urban Resilience Enabled with Asset and Disaster Risk Management Approaches and GIS-Based Decision Support Tools. *Appl. Sci.* **2023**, *13*, 2223. [CrossRef]
7. Fontana, C.; Cianci, E.; Moscatelli, M. Assessing Seismic Resilience of School Educational Sector. An Attempt to Establish the Initial Conditions in Calabria Region, Southern Italy. *Int. J. Disaster Risk Reduct.* **2020**, *51*, 101936. [CrossRef]
8. Grussing, M.N. Life Cycle Asset Management Methodologies for Buildings. *J. Infrastruct. Syst.* **2014**, *20*, 4013007. [CrossRef]
9. Tang, J.; Heinimann, H.; Han, K.; Luo, H.; Zhong, B. Evaluating Resilience in Urban Transportation Systems for Sustainability: A Systems-Based Bayesian Network Model. *Transp. Res. Part C Emerg. Technol.* **2020**, *121*, 102840. [CrossRef]
10. Esmalian, A.; Yuan, F.; Rajput, A.A.; Farahmand, H.; Dong, S.; Li, Q.; Gao, X.; Fan, C.; Lee, C.C.; Hsu, C.W.; et al. Operationalizing Resilience Practices in Transportation Infrastructure Planning and Project Development. *Transp. Res. D Transp. Environ.* **2022**, *104*, 103214. [CrossRef]

11. Wang, C.; Ju, P.; Wu, F.; Pan, X.; Wang, Z. A Systematic Review on Power System Resilience from the Perspective of Generation, Network, and Load. *Renew. Sustain. Energy Rev.* **2022**, *167*, 112567. [CrossRef]
12. Lee, S.; Ham, Y. Probabilistic Framework for Assessing the Vulnerability of Power Distribution Infrastructures under Extreme Wind Conditions. *Sustain. Cities Soc.* **2021**, *65*, 102587. [CrossRef]
13. Trindade, M.; Almeida, N.; Finger, M.; Ferreira, D. Design and Development of a Value-Based Decision Making Process for Asset Intensive Organizations. In *Asset Intelligence through Integration and Interoperability and Contemporary Vibration Engineering Technologies. Lecture Notes in Mechanical Engineering*; Mathew, J., Lim, C., Ma, L., Sands, D., Cholette, M., Borghesani, P., Eds.; Springer: Cham, Switzerland, 2019. [CrossRef]
14. Buck, C.; Clarke, J.; Torres de Oliveira, R.; Desouza, K.C.; Maroufkhani, P. Digital Transformation in Asset-Intensive Organisations: The Light and the Dark Side. *J. Innov. Knowl.* **2023**, *8*, 100335. [CrossRef]
15. Meschini, S.; Pellegrini, L.; Locatelli, M.; Accardo, D.; Tagliabue, L.C.; Di Giuda, G.M.; Avena, M. Toward Cognitive Digital Twins Using a BIM-GIS Asset Management System for a Diffused University. *Front. Built Environ.* **2022**, *8*, 959475. [CrossRef]
16. Chen, Z.S.; Yang, L.L.; Chin, K.S.; Yang, Y.; Pedrycz, W.; Chang, J.P.; Martínez, L.; Skibniewski, M.J. Sustainable Building Material Selection: An Integrated Multi-Criteria Large Group Decision Making Framework. *Appl. Soft Comput.* **2021**, *113*, 107903. [CrossRef]
17. Petchrompo, S.; Parlikad, A.K. A Review of Asset Management Literature on Multi-Asset Systems. *Reliab. Eng. Syst. Saf.* **2019**, *181*, 181–201. [CrossRef]
18. Piryonesi, S.M.; El-Diraby, T.E. Role of Data Analytics in Infrastructure Asset Management: Overcoming Data Size and Quality Problems. *J. Transp. Eng. Part B Pavements* **2020**, *146*, 4020022. [CrossRef]
19. Komljenovic, D.; Nour, G.A.; Boudreau, J.F. Risk-Informed Decision-Making in Asset Management as a Complex Adaptive System of Systems. *Int. J. Strateg. Eng. Asset Manag.* **2019**, *3*, 198. [CrossRef]