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A Systems Modelling Approach to Sustainability: From Qualitative Insight to Simulation

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Abstract

Sustainable development modelling presents inherent complexity, as it involves multiple stakeholders and the integration of economic, environmental, and social considerations under the Triple Bottom Line (TBL) framework. While this complexity is widely acknowledged, many existing approaches overlook early-stage divergence in stakeholder perspectives, ambiguity in system boundaries, and disagreement over indicator selection—all of which significantly influence simulation model design. This paper presents a hybrid modelling framework that integrates Qualitative System Dynamics (QSD) with Discrete-Event Simulation (DES) to support policy appraisal under the TBL perspective. QSD is used to develop a soft representation of the problem, capturing stakeholder views, identifying key performance indicators, and revealing interdependencies among TBL components. This conceptual model then informs the design of the DES, which facilitates the evaluation of alternative strategies through quantitative experimentation. Unlike existing methods that treat TBL components in isolation or fail to integrate conceptual insights, this framework incorporates a structured QSD stage to shape the DES model. However, the integration of QSD and DES raises challenges such as ensuring consistency in model translation and managing the subjectivity inherent in soft OR. The proposed approach highlights how combining soft and hard Operational Research methods enhances both model formulation and decision support. Rather than assuming straightforward implementation, the study discusses how QSD reduces modelling ambiguity while also introducing its own interpretive demands. The contribution lies in advancing hybrid modelling practice for sustainability analysis and reflecting on the value of soft OR in shaping quantitative modelling.

Keywords

Sustainable Development; Hybrid Modelling; Soft Operational Research; Qualitative System Dynamics; Modelling and Simulation

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