

A State-of-the-Art Review: Ireland, a Model State?

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The review established the state-of-the-art in hybrid simulation modelling and mixed-use methodologies focusing on their utility in the abatement of Greenhouse Gas Emissions efforts and the realisation of a circular green economy in Ireland by 2050. Ireland missed its EU 2020 climate emissions target and is not on the right trajectory towards decarbonisation in the longer 2030 and 2050 challenges (Environmental Protection Agency, 2019). Ireland's transition to a low-carbon, climate-resilient environment, society, and economy while meeting national and international emission targets is a priority for decision-makers. Treating waste as a resource and moving towards a more resource-efficient and circular green economy is also an objective. Agriculture is on course, to rise by 3% from current levels and will account for 38% of carbon emissions by 2030 (Environmental Protection Agency, 2018), mainly as a result of plans to increase the national herd (Department of Agriculture, Food and the Marine, 2015). To reduce carbon emissions, the Climate Change Advisory Council in Ireland has pointed to a need for an increase in carbon tax. Key action nine of the Government's Climate Action Plan commits to the implementation of a carbon tax rate of at least €80 per tonne by 2030, currently the cost is €20 per tonne (Government of Ireland, 2019).

Policymakers can use mathematical decision support models which can help design climate policies and select relevant climate change strategies. A simulation model can be used to represent the system, a simplified abstraction of reality which allows for the study of the system at a low cost. A system is a collection of entities (people, parts, messages, machines, servers,) that act and interacts together towards some end (Schmidt.Taylor, 1970). Problems in the real world usually depend on the influence of many variables. Intelligent decision making requires the appropriate use of many different models designed for specific purposes and not be reliant on a single comprehensive model of the world (Sterman, 1991). By setting up a range of "what-if" queries into the model, it is possible to elaborate which possible solution is the best compared to others (Hari & Taha, 2008). For a model to be useful to decision-makers, it must provide some view on future behaviour. (Meadows, et al., 1974) provides a valuable classification of the types of outputs models can provide. Multivariant relationships are introduced by having a computer model handle computation in practical applications. Models are classified as Simple or Complex. Simple models include Static, Deterministic, Linear and Continuous. Complex models include Dynamic, Stochastic, Nonlinear, and Discrete. Discrete Event Simulation (DES) is an operational tool designed for the optimisation of the system performance at a very detailed level. System Dynamics (SD) is an approach to understanding nonlinear behaviour of complex systems over time that uses stocks, flows, feedback loops, table functions and time delays. Agents Based Modelling (ABM) has autonomous agents which can make their own decisions acting within their environment. Hybrid mixed-method simulation is designed for both continuous and discrete parameters and can be found in the computer science literature since (Mušič & Matko, 1999).

The contribution addressed how to combine developing hybrid simulation techniques with established and matured practices such as Lean Six Sigma, which originates from Operations Research (OR). It applied the synthetic mode of thought which, when mapped to a system problem is called the systems approach. In this approach, a problem is not solved by taking it

apart but by viewing it as a part of a whole of a more significant problem. Putting things together, synthesis is the key to systems thinking just as analysis or taking them apart was to Machine-Age thinking. The differences between Systems-Age and Machine-Age thinking derives not from the fact that one synthesises and the other analyses, but from the fact that systems thinking combines the two in a new way (Ackoff, 1981). The systems thinking approach can be applied with (Senge, 1990) and (Checkland, 2000) in the field of Operations Research (OR). The research investigated the use of System Dynamics (SD) applied with Lean Six Sigma and the use of the DMAIC (Define, Measure, Analyse, Improve, Control) cycle. (Cardiel-Ortega, Baeza-Serrato, & Lizarraga-Morales, 2017) results show an improvement in the process performance by increasing the level of Sigma, allowing the validation of the proposed approach. While (Hari & Taha, 2008) maintain that Six Sigma needs more development to meet requirements. There is little literature on the use of SD with the Lean Six Sigma DMAIC cycle, which provides for further research opportunities.

The review analysed environmentally-focused models utilised in Ireland within the European Union such as the GAINS (Air pollution Interactions and Synergies) model used for air pollutants, the JRC-EU-TIMES, (Joint Research Council-European Union-The Integrated MARKAL-EFOM System) and the Irish TIMES model used for energy, the integrated modelling project Ireland (GAINS & TIMES), and the environmental, economic model ENV-Linkages. It is useful for the future, (Kelly, Chiodi, Fu, Deane, & O'Gallachóir, 2013) to have experience of reconciling the energy pathway recommendations from the Irish TIMES model with the GAINS Ireland modelling system. This technique will allow those pathways to be assessed in the familiar GAINS format by the European Commission or other international policymaking bodies during the negotiation and review processes for global climate and air policy. The teams showed a soft link is possible as there is no automated solution to link the two models. This enables assessments of what such climate optimisations imply for legally binding air pollutant targets for Ireland, and it further allows the estimation of air pollutant-related impact costs by using their marginal damage valuation methodology. Supplementing this modelling with tailored policy research will help to identify practical means of delivering better policy decisions for Ireland in the future. (Kelly, A., 2013) recommends further research is needed to precisely assess the practicality of any increased biomass use in Ireland consistent with appropriate policies and technologies. Further research should assess the directly corresponding health and environmental impacts that could otherwise occur due to associated increases in the levels of air pollutants across Ireland. The results highlight the importance of integrated policy analysis which needs to take a broader perspective with national decision-making which considers a policy change from multiple angles such as air, climate, economy, and health. Often, a lack of understanding of the systems assessed is the biggest weakness in an assessment. One example of this is in understanding the decision-making process (Parson, 1997), (European Environment Agency, 1998).

Is Ireland a model state? While there is a lot of work in simulation modelling in areas such as computer science, healthcare, environment, and Operations Research (OR), different facilities look at simulation independently. The literature established that simulation modelling is becoming an interdisciplinary field with hybrid models of simulation used in addressing real-world problems in all disciplines and provides the most opportunities for further research. For this project SD could be applied to model the overall system (carbon emissions), DES to model the parts within the system (production process of the raw materials) and ABM to model the agents acting within the system (uptake of farmers growing hemp. SD modellers should explore the progress made in the rapidly evolving area of hybrid modelling and collaborate with others who have developed successful hybrid modelling methods (Sterman, D, J., 2019). Part of the state of the art will be the expertise to draw from the various tools available and pick the ones that are most appropriate for the task and problem at hand. The field need to have a multi-faceted approach binding under an organised framework, a Nexus.

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