A multi-method approach for mixing system dynamics and Bayesian network models: design classes and illustrative case studies

1 Background

The Capability Systems Centre (CSC) is exploring the possibility of collaboration with researchers with expertise in the development of multi-method modelling approaches to support complex problem solving and decision analysis. We are particularly interested in the development and application of approaches combining systems dynamics modelling and Bayesian networks. CSC calls for EOIs from interested researchers with the suitable background and expertise to tackle the following work package.

2 Work package overview

A major research direction in the CSC is the development and use of system dynamics simulation modelling to support decision making in complex problems. CSC is interested in exploring the potential of leveraging other modelling and analysis methods to complement its evolving system dynamics modelling capabilities. Towards this goal, the purpose of this work package is to: (a) develop a generic multi-method methodological framework for combining system dynamics and Bayesian network modelling approaches, and (b) test applicability and utility of the proposed approach in the applications areas that CSC is interested in.

2.1 Scope

System dynamics (SD) is a useful simulation-based methodology for explicitly capturing the fundamental causal processes and relationships that derive changes in the system behaviour over time. The methodology is focused on understanding the effects of feedback interactions, delays, and non-linear relationships between the system elements, on the holistic system behaviour and the effectiveness of various decision options.

Bayesian network (BN) is a probabilistic modelling technique used in modelling system relationships containing some degree of uncertainty caused by imperfect understanding or incomplete knowledge of the system's states (Chen and Pollino, 2012).

2.2 Focus

There is already a recognition of the complementary views that both SD and BN can bring into modelling complex problems, and the potential value of combining both approaches into an integrated modelling framework (e.g. Kelly et al., 2013; Molina et al, 2013). However, aside from these claims and aspirations and some limited applications, there exist a crucial gap around ways to mix SD and BN in an explicit and coherent methodological framework. This means the modellers have very limited guidance into the spectrum of methodological designs for mixing SD and BN, the offerings of these designs to modelling insights to the problem, and the actual nuts and bolts of mixing both approaches in practice. A multi-method methodological approach for combining SD and BN is crucial for providing insights into the insight into the philosophical, methodological and technical considerations when using each method within a mixed method design.

In this study, we aim to contribute to bridging this fundamental research gap, by addressing the following questions:

1. Drawing on existing literature on mixing SD and BN, what are the implications of these studies for the multi-method design approach?

2. How can we draw on the theories of multi-method (e.g. Minger et al., 1997;) and hybrid modelling (e.g. Swiner and McNaught, 2012) approach to define and compare the design classes for mixing SD and BN?
3. How can we use a case study approach to illustrate and validate the proposed approach? What lessons can be gained from the case studies into the implementation of SD and BN integrated models, and the practical considerations?

2.3 Milestones and Deliverables

Milestone #	Milestone description	Date
1	Initial workshop to establish working arrangements, further define the problem and to clarify any questions or issues.	Within two weeks of commencement of agreement, Location: TBD
2	Literature review and analysis of past studies employing both SD and BN modelling approaches. The analysis should result in explicitly categorizing paper in terms of their multi-method stance (Howick and Ackermann, 2011) by identifying: (a) the adopted problem view, (b) their descriptions of mixing methods, (c) rationale for mixing methods, and (d) dominance of methods. The analysis also should point to any limitations in the employed research designs, and their implications for future research.	
3	Draw on existing theories on multi-method and hybrid modelling to propose possible design classes for mixing SD and BN.	
4	Propose a plan for the implementation of the proposed design in an application area that CSC is interested in (TBD). The implementation plan should clearly articulate the data requirements, modelling tools, and modelling output to be generated.	
Deliverable 1: Joint paper with CSC staff covering Milestones 1-4 to be submitted to relevant conference or a journal (TBD)		
5	Develop and use a series of case study vignettes to validate and illustrate the application of the proposed design classes in practice. This step should result in: (a) a set of modelling artefacts showcasing the design classes, and (b) implementation and technical considerations involved in each design.	
Deliverable: Joint paper with CSC staff covering Milestones 1-5 to be submitted to relevant journal (TBD)		

3 References

Chen, S. H., & Pollino, C. A. (2012). Good practice in Bayesian network modelling. Environmental Modelling & Software, 37, 134-145.

Howick, S. & Ackermann, F. (2011) Mixing OR methods in practice: Past, present and future directions. European Journal of Operational Research, 215(3): 503-511

Kelly, R. A., Jakeman, A. J., Barreteau, O., Borsuk, M. E., ElSawah, S., Hamilton, S. H., ... & van Delden, H. (2013). Selecting among five common modelling approaches for integrated environmental assessment and management. Environmental modelling & software, 47, 159-181.

Mingers, J. & Brocklesby, J. (1997). Multimethodology: Towards a Framework for Mixing Methodologies. Omega, 25(5): 489-509.

Molina, J. L., Pulido-Velazquez, M., Llopis-Albert, C., Pena-Haro, S., 2013. Stochastic hydro-economic model for groundwater quality management using Bayesian networks. Water Sci Technol. 67(3), 579-586. doi: 10.2166/wst.2012.598

Swinerd, C. & McNaught, K. R. (2012). Design classes for hybrid simulations involving agent-based and system dynamics models. Simulation Modelling Practice and Theory, 25: 118-133.

4 Requirements

Please provide:

- A brief CV describing your research background.
- A focused statement of your suitability for undertaking the work detailed above.
- A detailed description outlining how you would undertake the research described above.
- A brief project plan attaching dates and an outline budget to the milestones outlined above.

5 Submissions

Submissions must be lodged via email, as a PDF file, to: capabilitysystems@adfa.edu.au.

Inquiries may be directed to: Associate Professor Mike Ryan, Director, Capability Systems Centre, capabilitysystems@adfa.edu.au.