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Creating a *Sustainability Scorecard* as a predictive tool for measuring the complex social, economic and environmental impacts of industries, a case study: Assessing the viability and sustainability of the dairy industry

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ABSTRACT

Sustainability is a key driver for decisions in the management and future development of industries. The World Commission on Environment and Development (WCED, 1987) outlined imperatives which need to be met for *environmental, economic* and *social* sustainability. Development of strategies for measuring and improving sustainability in and across these domains, however, has been hindered by intense debate between advocates for one approach fearing that efforts by those who advocate for another could have unintended adverse impacts. Studies attempting to compare the sustainability performance of countries and industries have also found ratings of performance quite variable depending on the sustainability indices used. Quantifying and comparing the sustainability of industries across the *triple bottom line* of economy, environment and social impact continues to be problematic. Using the Australian dairy industry as a case study, a *Sustainability Scorecard*, developed as a Bayesian network model, is proposed as an adaptable tool to enable informed assessment, dialogue and negotiation of strategies at a global level as well as being suitable for developing local solutions.

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1. Introduction

Over two decades ago, the Bruntland Report defined sustainable development as 'development that meets the needs of current generations without compromising the ability of future generations to meet their own needs' (WCED, 1987). The purpose of this report was to generate a more integrated approach to sustainability, emphasising that multiple systems are at work: economic growth, development of social equality and improved protection of the environment. Its proposals were endorsed by world leaders at the United Nations Conference on Environment and Development in Rio de Janeiro in 1992 and the World Summit on Sustainable Development in 2002 in Johannesburg. Progress in developing strategies to improve sustainability has been hindered, however, by debate over definitions and intent, and the lack of tools to assist the making of an integrated assessment of risk and the modelling of potential positive and negative impacts of strategies employed in one system (e.g. economics) on others (e.g. environment) (Barlund, 2004–05; Drexhage and Murphy, 2010; Staniunas et al., 2012).

In 1996, the International Institute for Sustainable Development held a meeting in Bellagio, Italy to review progress made in sustainable development since the release of the 1987 Brundtland Report to develop principles that will underpin ongoing assessment of progress, and to develop strategies for improving sustainability (Hardi and Zdan, 1997). Other specialist meetings have followed, aimed at developing a more coordinated approach to assessing and improving sustainability. A tool which can provide an integrated assessment of economic, environmental and social sustainability as complex interacting systems, however, has yet to become available for industries, governments and global monitoring bodies to understand current functioning and the risks to be addressed.

In the absence of such a tool, an integrated assessment of sustainability is very challenging. Consequently, much debate ensues

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within industry and government about issues such as formulation of policies and strategies, and prioritisation of actions (Barlund, 2004–05; Drexhage and Murphy, 2010; Staniunas et al., 2012). Furthermore, such a tool would be able to aid industries and communities in understanding and assessing their sustainability with the purpose of implementing strategies for improved practice (Barlund, 2004–05). By engaging local stakeholders, environmental, economic and industry experts, and involving policy and political decision-makers, useful definitions and strategies are likely to emerge from practice (Sneddon et al., 2006).

A common approach to integrated assessment is via a *triple bottom line* (TBL) of economic, environmental and social domains. However, while a TBL approach to sustainability is conceptually appealing, quantifying and comparing sustainability performance of industries across these domains has continued to be problematic since each domain is a complex system in its own right with unique parameters which must be analysed individually and collectively (Sneddon et al., 2006). At present, measures of risk and success and largely discrete strategies for sustainability have been developed for each of these three domains in isolation from one another, with no analysis of how activity for improvement in one area might affect another (Sneddon et al., 2006).

There is an increasingly strong political desire to measure sustainability (Bohringer and Jochem, 2007), which is evidenced by the Australian Government initiative, *Sustainable Australia – Sustainable Communities* (Australian Government, 2011). As the need for global co-operation, comparisons of performance and sharing of strategies grows even stronger with the impacts of climate change being felt, growing populations, diminishing resources and swell in consumer demand (stimulated by economic growth in developing countries), access to a flexible sustainability tool which is transparent, credible, defensible and which prevents misinterpretation by policy makers and the public is of paramount importance. It is crucial that the methodology and sustainability assessment components are understood by policy makers. Furthermore, there has to be a sound grasp and appreciation of the uncertainty inherent in the sustainability model and calculations so that policies are made and communicated accordingly. The converse would give rise to policies which are assessed and informed by misleading and incorrect measures and findings (Bohringer and Jochem, 2007).

TBL assessment of complex issues commonly entails the development of composite indices, which are weighted combinations of selected indicators of the three economic, environmental and social domains (Bohringer and Jochem, 2007). A more general approach to modelling complex systems such as TBL aggregation and quantification is through Bayesian networks (BNs) (Johnson and Mengersen, 2012). A BN has the ability to reflect more complex interactions between indices and indicators, incorporate uncertainty in model inputs and outputs, and provide more detailed probability estimates about the TBL domains for key processes and sectors of the industry based on the whole system.

An international workshop was convened in Oslo in 2009 to compare the application of (BN) analyses to a range of environmental and resource management problems and to identify common modelling strategies and understand questions for further research (Barton et al., 2012). However, to our knowledge BNs have not been used to evaluate TBL for sustainability of an industry. Moreover, the outputs of BNs are typically in the form of probability tables which are not immediately accessible to industry managers and decision-makers.

The purpose of this article is to develop a BN for industry sustainability, using the Australian dairy industry as a case study, and to propose an adaptable *Sustainability Scorecard* based on the BN outputs. We argue that this *Sustainability Scorecard* will greatly enhance informed assessment, dialogue and negotiation of strategies at a global level and for the development of local solutions.

1.1. Working with complex interacting systems to develop reality-based strategies

A complex system is one in which the network of factors that affect the system, and their interactions, is so multidimensional and complicated that it is impossible for a human to keep track of the resultant processes. Moreover, the system can change through self-organisation and complex patterns can arise from relatively simple interactions (Capra, 1996; Johnson and Mengersen, 2012).

Sustainability, with its many interacting factors and processes, is such a complex system. For example, primary industries function in contexts ranging across farm, factory and market, and are affected by and impact upon environmental, social and economic factors. These industries can react to these impacts by *self-organising* (not always positively), in that they do not require external intervention to thrive or deteriorate. They can also exhibit emergent behaviour since intervening in one part of the sustainability system can have unintended and quite extreme effects in seemingly unrelated other parts of the system (Johnson and Mengersen, 2012).

1.2. Complex systems and Bayesian networks

BNs are mathematical models that can be used to describe complex systems, in particular the key factors and interactions of the system and the nested systems within larger systems (Johnson and Mengersen, 2012). The model structure and parameters may be learnt entirely from data or elicited from experts or a combination of both (Jensen and Nielsen, 2007). In the context of industry TBL sustainability, the BN can be structured to reflect the key contexts in which that industry functions and the relevant indicators relating to the TBL domains. In the dairy sustainability case study considered in this paper, the contexts are farm, factory and market, and each of these contexts has factors (variables) relating to environment, economics and social impact. The BN can thus be viewed as a hierarchical model with the high-level model giving an uncluttered overview of the system, and the nested sub-models containing more detailed information (Johnson and Mengersen, 2012). Each of these nested sub-models has multiple factors too, e.g. the factors which affect a farm economically; the environmental impacts specific to farm, factory or market.

These key factors and sub-models are graphically represented as *nodes* in the BN, and the relationships between the nodes are represented as directed arrows. The BN representation for the Dairy Australia sustainability case study is illustrated in Fig. 1.

In Fig. 1, each of the key sustainability indicators for farm, factory and market is assessed in detail through sub-indicators. For example, the Dairy Australia case study has five key indicators for economic sustainability at the farm, and each of the key indicators typically has three to five sub-indicators, which combine to give an evaluation of the key indicator.

For each sub-indicator, existing measures are identified which give an appraisal of the current state of each of the sustainability sub-indicators. The measures are chosen based on their informativeness about the corresponding sub-indicator and the availability of data to quantify them. This quantification is usually described as a probability distribution or a probability table and is conditional on the nodes that feed into or impact on the measure. The data sources may include relevant observations, experiments, industry reports, results from prior studies or published literature, expert judgement and so on. The information is then propagated through the network (by multiplying the conditional probabilities). By this process, the target nodes describing sustainability from the farm,

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