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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.

Keywords:
Sustainability
Triple bottom line
Environmental management
Bayesian network modelling
Sustainability scorecard
Sustainable industry
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 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 modeling 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 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 Figure 1.

![Figure 1. Summary of the Dairy Australia Sustainability Scorecard Bayesian network with sub-models (rectangles with rounded edges) and nodes (ellipses)](image-url)
In Figure 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, factory and market perspectives and the economic, environment and social domains, as well as the overall sustainability node, are thus quantified using all of the information contained in the network.

Representing these BN model outputs as a Sustainability Scorecard allows for both holistic evaluation of sustainability and specificity of analysis. For example, a BN can represent sustainability at the local community level to examine their unique features and challenges. The scores of industry in particular sites or settings can be aggregated upwards to give an overall industry score for the larger region or the country. The scores can also be disaggregated to drop back down to that level of detail, specific to the BN for specific regions, to retain analysis of the issues specific to unique settings, i.e. the BN model can be constructed as a hierarchical model, or an object-oriented BN, which can be designed to show or hide details of the model depending on the audience or purpose (Johnson and Mengersen, 2012).

One of the strengths of a BN is that it is able to operate in a predictive or diagnostic way, as well as an inter-causal way (commonly referred to as “explaining away”) because the framework is based on Bayes theorem (Pearl, 1988; Taroni et al., 2006). In other words, even though the model may be constructed in a “top-down” manner, the queries can be “bottom-up”. For example, we can ask the question “For economic sustainability to be high, what are the necessary adjustments that need to be made to the economic indicators” or we can ask “If the sustainability score of each of the TBL dimensions improve by 10%, what is the predicted improvement in the overall sustainability score?”.

Because the nodes, indicators and measures for the BN can be developed and customised by and for the industry by the range of stakeholders in that industry, there is an opportunity to source converging evidence of key issues and find agreed upon measures for important variables. It is also possible to have timely warning of emerging issues and to work collaboratively to reconfigure the network to assess the impact of those issues (Johnson and Mengersen, 2009). - a BN ‘is always a work...
in progress’ (Johnson and Mengersen, 2012, p 485). This approach, through engaging stakeholders involved in and affected by an industry, generates ownership of the findings and the action required to position the industry for sustainability (Johnson and Mengersen, 2009), which is critical when diverse interest groups may have competing or conflicting interests (Dimitrov and Sami, 2010).

The forces which dominate the social, economic and environmental sectors, the decision-makers who have the power or influence to accept or reject change, cannot be ignored, if change is to be achieved (van Kerkhoff and Lebel, 2006). It may be that part of the problem with the progress of sustainable development in the past has been the traditional divide between those undertaking the systematic research and those required to take up and act on the results. The dissemination of research results usually only occurs on completion, in a unidirectional, linear communication (van Kerkhoff and Lebel, 2006), whereas, as grounded researchers explain, ownership of ideas and a willingness to implement these relies on a more collaborative approach from the outset. It requires acknowledgment of the fact that experts exist in all spheres and need to be able to share information and to engage in debate, in order to come to agreement on issues, assessment tools, priorities for remediation and an optimal approach to solving problems (Corbin and Strauss, 2008; Johnson and Mengersen, 2009) like sustainability.

Developing a BN with industry stakeholders as a measurement and planning tool addresses the two critical factors which have stalled progress on sustainability to date, namely, dealing with complexity across the multiple systems which affect and are affected by sustainability and engaging the divergent interest groups of environmental, economic and social systems in dialogue which generates a collaborative, coordinated effort.

2. Materials and methods

For concreteness, we describe the development of a TBL BN and corresponding Sustainability Scorecard for the Australian dairy industry. Like most primary industries, the viability of this industry is dependent on how well it addresses and adapts to the unprecedented and long-term challenges of climate change, and its ability to adopt more sustainable practices and minimise negative impacts. The successful adaptation of the dairy industry is critical to addressing the global challenge of providing a secure supply of food globally, and specifically in the Asia-Pacific region.

The development of the BN and corresponding Sustainability Scorecard is an iterative process with five key stages: Design, Quantify, Validate, Evaluate and Adapt.
2.1 Design

The BN was constructed using an expert panel comprising a range of industry stakeholders. The design phase thus included both the design of the stakeholder engagement processes for developing the BN and the design of the BN model structure, which includes the identification of the nodes and interactions between the nodes.

2.11 Stakeholder Engagement

For the dairy industry case study, stakeholder engagement was undertaken through three workshops with the range of stakeholders and through ongoing collaboration with key informants:

1. In March 2011, a workshop was held with representatives from Dairy Australia to develop a framework for a predictive tool to measure the sustainability of the dairy industry. A collaborative, industry based approach was selected to maximise industry participation and strengthen industry confidence in and ownership of the process.

2. In June 2011 a workshop was held with representatives from Dairy Australia and the Dairy Manufacturers Group. During the workshop, participants endorsed examining the environmental, economic and social impacts relating to farm, factory and market, to form
the basic framework for a Sustainability Bayesian network (Figure 1) and for the eventual adaptation of the BN to develop a *Sustainability Scorecard* for ongoing industry self-assessment.

3. In April 2012 a workshop was held with representatives from Dairy Australia and the Dairy Manufacturers Group to review the sustainability indicators, and to refine and agree on the BN model structure, nodes and measurements, suggested weightings and to discuss possible scenarios for testing and querying the model.

### 2.12 Design of BN model structure

The challenge with building a BN is determining the level of detail necessary to assess the critical issues for that industry, to be alert to risks and to be able to evaluate complex, interacting driving forces within and between the systems. That is, how many layers of nested systems (sub-models) and how many variables for each sub-indicator need to be measured, to rigorously assess these variables, and how many sub-indicators are required to represent a key sustainability indicator; while keeping the choice of variables and their measures simple enough to be comprehensible (Johnson and Mengersen, 2012). Bayesian networks can make complex systems and their functioning understandable by breaking them down into their smaller sub-systems to examine smaller problems. Figure 3 below illustrates how the system being modelled might be broken down to be able to analyse the layers of sub-systems which affect it.

The BN for sustainability in the dairy industry comprises two sets of target nodes: a) those that describe the context, i.e. Farm, Factory, Market and b) those that describe the sustainability domains, i.e. Environmental, Economic, and Social. The sub-models in the BN ‘open out’ to show the nodes that describe that sub-network. For example, Figure 3 shows the *Economic: Farm*, sub-network, with five key sustainability indicators linking to it: *Workforce: Farm; Economics: Farm; Profitability: Farm; Physicals: Farm*; and, *Market: Farm*. Each of the key indicators is modelled as a sub-network with sub-indicators combining to give an overall assessment of that key indicator. For example, sub-indicators *Employment, Productivity* and *Management* combine to give a sustainability outcome for key indicator *Workforce: Farm*. Each of the sub-indicators is populated by the synthesis of one or more measures. For example, sub-indicator *Productivity* takes its information from the measure *Milk Produced*. Very complex systems can be described in this manner, with measures specific to each variable in each sub-network, allowing a depth of analysis to be explored.
Figure 3. Example of a sub-network, its nested systems and variables

Quantify

In quantification, the challenge is to determine appropriate indicators, including the identification of variables for which reliable measures already exist, which can be incorporated into the BN, e.g. global indices such as the Carbon Footprint or dairy industry accreditation standards. There are many sustainability tools and measures that have been developed, with varying degrees of rigour, which need to be examined, to assess their value and potential use. Measures need to be considered and agreed upon in collaboration with industry and other stakeholders.

At dairy industry stakeholder workshops and in meetings with key informants, initial indicators were put forward and measurement tools identified, which could be incorporated into the network. Two approaches to identifying frameworks and/or tools were used.

First, a review of industry measures based on searches of 11 primary electronic English
language library databases, most of which are linked to a range of other databases that expanded the scope of searches for this study, was undertaken. These databases were: Academic Search Elite (via EBSCOhost), ASM Handbooks Online, BEDP Environment Design Guide, Compendex (via Engineering Village), CRCnetBASE, EBSCOhost, Ecospecifier, GreenFILE (via EBSCOhost), Informit, ProQuest Research Library, ScienceDirect, Scopus, SpringerLink Online Journals, UlrichsWeb.com, and Web of Knowledge.

The search strategy is detailed in Table 1 (below), outlines the process steps by which the 72 publications were identified. These publications were used to confirm the comprehensiveness of the nodes, indicators and measurements and to confirm measures for benchmarking or other comparisons, as standardised industry measures or sustainability indices. Overall, this review utilised a total of 357 different library databases to search books, journals, magazines, trade publications, government reports and a range of other documents dating from 1998 to 2011 for relevant data. Publications were included if they defined or evaluated sustainability based on the three TBL dimensions or other similar dimensions and were peer reviewed. They were excluded if they related only to single bottom line dimensions, such as environment.

Table 1. Search strategy

<table>
<thead>
<tr>
<th>Stage</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total items identified by primary searches</td>
<td>76039</td>
</tr>
<tr>
<td>Total items after first limiter</td>
<td>11505</td>
</tr>
<tr>
<td>Total items after second limiter</td>
<td>4011</td>
</tr>
<tr>
<td>Items selected for inclusion in bibliography</td>
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</tr>
<tr>
<td>Bibliography items after first removal of duplicates</td>
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<tr>
<td>Final bibliography</td>
<td>690</td>
</tr>
<tr>
<td>Review reference list</td>
<td>77</td>
</tr>
<tr>
<td>TBL framework utilised</td>
<td>72</td>
</tr>
</tbody>
</table>

Second, industry relevant sustainability frameworks or tools were identified, including: Vital Capital Survey, Nestle, SAFE framework, Lactalis / Parmalat / Pauls (under internal corporate review at time of Stakeholder review), DairySAT, Danone Sustainability Report (performance indicators), Fonterra Sustainability Indicators, RISE, Unilever Sustainable Code, and GRI (Global Reporting Initiative).

A review of these tools was undertaken to identify relevant indicators and measures. The Bellagio Principles were used as a guiding philosophy to define our indicator criteria and requirements.
BNs are ‘quantified’ by assigning conditional probability distributions to the nodes. Because of the type and nature of the available information, in this case study all of the key indicators, sub-indicators and measures (i.e., all of the nodes in the BN) were discretised into a set of states. Each node was assigned three states, High/Medium/Low, where these were defined uniquely for each state in collaboration with the stakeholders (see Figure 4). Probabilities were then assigned to the node states (for example: probability that the score reflects sustainable practices/probability that the scores suggests a risk, etc) based on available evidence.

Although the overall BN may be complex, determining the probabilities for an individual node is based only on the nodes that directly impact on that node (known as parent nodes). In other words, the conditional probability distribution for a key indicator node is completely determined by the synthesis of the sub-indicator nodes connected to it. In this case study, weightings were assigned to each of the parent nodes when combining them. The stakeholders advised of the relative influence or weightings of the parent nodes. The default assumption was that each parent node contributes equally to the overall score of the child node.

The final outcome was the aggregated probability scores for the sustainability of the industry being assessed, i.e. the ‘Overall Sustainability Score’.

Importantly, all of the probabilities related to these outcomes are determined in light of all of the other factors and all of the information in the BN model, that is, systems are cross-checked for their potential impact on each other. For example, the probability of financial sustainability may be high but if a measure for a node elsewhere is changed (e.g. environment was affected by a flood) then the new measure for environment would be taken into account in the revision of the financial sustainability.

The quantification of the Sustainability Scorecard is based on the probability outputs of the Sustainability BN. For example, the Scorecard designed for the dairy industry study reports the probabilities of a High sustainability score for each of the TBL domains, and for each of the key sustainability indicators. The probabilities are colour-coded in traffic-light form, with shades of green indicating that the factor has a high chance of achieving high sustainability in that TBL domain, shades of orange indicating a medium chance, and shades of red indicating a low chance (see Figure 4 below).
The Sustainability Scorecard can be validated in two ways, namely, internal validation and stakeholder validation. Internal validation involves cross-checking the BN probabilities for
consistency. For example, when changing a probability for one node, the consequent changes in the probabilities of other nodes should conform broadly as expected. Stakeholder validation involves critical review of the Bayesian network and Scorecard design and outputs from differing stakeholder perspectives and needs (for example stakeholders from the farm, factory and market perspectives).

Internal validation was undertaken by members of the research team who were experts in mathematical modelling. The consistency of the probabilistic inputs and outputs in the BN was confirmed through careful inspection of the coherence and impact of parent node CPTs on child node CPTs throughout the model. Stakeholder validation was undertaken through both the dairy industry stakeholder workshops and ongoing meetings with stakeholders and experts in the field. These interactive workshops provided the opportunity to inspect, test and refine the quantitative model.

Evaluate
The Sustainability Scorecard can be used for a wide range of evaluations. Key drivers of sustainability can be identified by interrogating the BN to investigate which factors have most impact on nodes of interest. Information gaps can be identified through the process of designing and quantifying the BN. Evidence and parameter sensitivity analysis complement this process to earmark those parameters that require more attention to improve the predictive accuracy of the model. Scenario (“what if”) evaluations can be undertaken by changing the probabilities in the BN in accordance with a specified scenario and inspecting the resultant change in probabilities of nodes of interest.

One of the strengths of a BN is that it is able to operate in a predictive or diagnostic way (“what if” assessments) as well as an inter-causal way (“explaining away”). In other words, even though the model is constructed in a “top-down” manner, the interrogations can be “bottom-up”. For example, questions can be asked, such as, “For economic sustainability to be High what are the necessary adjustments that need to be made to the economic indicators” or “If the sustainability score of each of the TBL dimensions improve by 10%, what is the predicted improvement in the overall sustainability score?”

The Sustainability Scorecard (see Figure 5) aims to capture information which can also be used as a tool to provide alerts to risks and indicators of issues which need to be addressed so that the industry is positioned to anticipate and respond to emerging issues, e.g. resulting from climate change, shifting economic (protection) policies in purchasing countries, resource degradation or loss. Such data assists in the negotiation of risk management strategies and proactive planning for the short, medium and long term. The tool was developed to have the capacity to model scenarios to understand the complex interactions of change in one area with impacts in others, to make optimal decisions and reduce the risk of unintended negative consequences. Development of the scorecard to establish a baseline of performance on the range of critical variables means that the industry can then be positioned to model
scenarios for problem solving, to understand how strategies for improvement in one area might affect risk factors in others.

Figure 5. The Dairy Sustainability Scorecard

Adapt

The BN model can be readily adapted and refined resulting from changes being identified during the development, testing and evaluation of the model. Furthermore, new information or research can be incorporated as it becomes available, so that it is a dynamic, living model, reflecting current
knowledge and uncertainty (Johnson and Mengersen, 2012). It is advisable to put regular model reviews in place, such as annual reviews to prompt a re-assessment of the state of the art in the sustainability model. This final stage of the development cycle ensures that the model reflects current trends, research and information and continues to be an effective tool to guide policy development and evaluation.

3. Discussion

The Sustainability Scorecard is a highly adaptable measurement tool with capacity to enable informed assessment, dialogue and negotiation of strategies at a global, national, or local level. The Dairy Australia case study demonstrates the value of stakeholder engagement of divergent interest groups for developing indicators and measures across multiple systems which affect, and are affected by, sustainability. The Sustainability Scorecard is a transparent and independent means of measuring the status of an industry and changes that occur over time, highlighting opportunities and challenges for stakeholders and the industry as a whole. Where possible, this Sustainability Scorecard has incorporated existing validated measurement tools, industry measures, global indices, and local assessments. It can be used for benchmarking and sharing of good practice between regions.

It is acknowledged that the model adopted in this paper to underpin the Sustainability Scorecard is one of a range of potential approaches and that, as with all models, the results are indeed reliant on the model structure and composition. For example, the BN model structure will be influenced by the stakeholders involved during the decision making process; if another group of people from a different lobby would have been chosen, the output of the model might be different. Since sustainability is an issue for the whole society in which different interests and point of views intersect, this should be acknowledged in the design process of the model. Notwithstanding these limitations, the distinct advantage of the proposed approach is that it is both highly structured, in that it requires a formal model comprising carefully defined and quantified nodes and links, and is highly transparent, in that the conceptual model and probabilities used to quantify the model are displayed in a simple and interpretable manner. This intentionally facilitates critical examination and debate among users. By design then, the model structure and inputs are easily changed to represent other interests and views. This is considered to be a strength of the model.

The BN model provides a rigorous framework for the Sustainability Scorecard to assess and quantify sustainability performance within and between systems, which could readily be adapted for use in a range of other industries. The effectiveness of the Sustainability Scorecard depends on the veracity of the indicators, the validity of the measures and the active participation of stakeholders (Dimitrov and Sami, 2010). However, building the level of collaboration required between stakeholders with conflicting or competing interests can be challenging. For example, some indicators may require financially sensitive data which could have the potential to compromise market advantage
It is therefore important to develop a high level of trust amongst the stakeholders, ensuring key informants are identified to underpin the process and that astute workshop processes are utilised when stakeholders engage as a collective.

Use of a scorecard to establish a baseline, against which to measure change over time and in response to any changing parameters, allows the industry and their stakeholders the ability to discuss and collaboratively consider strategic interventions for aspects that are identified as being at risk. Moreover, a Sustainability Scorecard allows stakeholders to:

- Identify key drivers and key weaknesses of sustainability
- Evaluate the overall state of sustainability for the modelled system
- Inform policy proactively
- Assist communities and industry to anticipate and adapt (future focus vs reactive)
- Use data to inform planning and policy discussions
- Develop strategies for involving diverse stakeholders through a transparent engagement process.

4. Conclusion

The capacity to use existing industry measures and global environmental, economic and social indices suggests the Sustainability Scorecard could be used for standardised comparisons with similar industries in other countries, while having the ability to be customised at the local level for development and testing of improvement strategies. In other words, the scorecard can be updated to mimic a strategy which is to be implemented within one domain and then predict the positive or negative impacts on another domain. For example, a strategy for improved environmental resource management can be entered into the BN model and the scorecard can then be queried for its impact on the economic and social domains. This demonstrates the “ripple” effect of the complex system of indicators and its interrelated impacts. Importantly, the scorecard is able to assist in identifying ways to increase overall sustainability while mitigating negative factors. It can therefore provide a flexible and robust tool for fact based analysis and collaborative problem-solving, which are paramount to support negotiation of a consensus on strategies and decision-making.

Declaration of competing interests
The authors declare that they have no competing interests.

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design; data collection (workshops); the writing of this paper; and, the decision to submit the article for publication.

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References


Table 1: Search strategy

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Figure 1. Summary of the Dairy Australia Sustainability Scorecard Bayesian network with sub-models (rectangles with rounded edges) and nodes (ellipses)

Figure 2: Schematic diagram of the phases involved in developing the Dairy Scorecard Bayesian network model

Figure 3. Example of a sub-network, its nested systems and variables

Figure 4. Example of a probability table

Figure 5. The Dairy Sustainability Scorecard