

# Build Collaborative Models or Capacity? Comparison of Techniques for Building Bayesian Networks for the Natural Resource Management Regions of Australia

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## EXTENDED ABSTRACT

It is becoming more widely acknowledged that in order to build appropriate decision support systems (DSSs) and models, stakeholder consultation is an important part of the model development process, promoting shared learning and final acceptance of the model. The degree to which stakeholders are engaged in the development of such models can vary from information sessions about the model that is being developed to more active and frequent collaboration into the development process.

A different approach to stakeholder participation is being explored through a project called Landscape Logic (<http://www.landscapellogic.org.au/>), using Bayesian Networks. This collaborative project aims to produce BNs to assist Australia's 56 Natural Resource Management (NRM) Regions (<http://www.nrm.gov.au/index.html>) make better informed investment decisions to improving the condition of their natural resources and communicate these decisions to stakeholders. Two concurrent approaches to BN development are being carried out in this project, each with different levels of participation from the stakeholder groups. One is building capacity in the NRM Regions so they can construct their own BNs (*Capacity building*). The researchers' involvement in this approach is to train the NRM regional staff in BN development and then supervise them while they develop BNs to assist them in making their investment decisions. The other is the more widely used approach where the researcher develops the model with periodic collaboration and input by the stakeholders (*Collaborative Model building*).

The project is being conducted in partnership with 6 of Australia's 56 NRM Regions, 3 in Tasmania and 3 in Victoria. Although the NRM Regions have similar objectives, they have developed different approaches to decision-making. The level of experience also differs between the States with Tasmanian regional bodies being formed in the last 5 years while the Victorian regional bodies have

been operating for over a decade. The project inadvertently presents an opportunity to trial the success and adoption of the BNs using two levels of stakeholder engagement, and then to compare the outcomes across a small sample of NRM Regions and States.

The results presented here focus upon the success of the capacity building in the NRM Regions as this has been the main focus of the project to date (Only one of the four years of the project duration). The NRM Regions remain very enthusiastic about developing their own BNs, but their progress is limited primarily by the time that they can devote to their BN development. They have generally conceded that the BN development will proceed in correlation with their related planning activities so as to not create unnecessary additional work. A long time lag in the development of the BNs increases the risk that the NRM Regions BN building capacity will be weakened by their rapid turnover of staff and shifting organisation demands. One option to accelerate the BN development is to provide an additional short term regional staff member to focus upon BN development but this could jeopardise some of the potential benefits of the process when driven by the organisation.

The NRM Regions still strongly support the notion that building their capacity in BNs is a feasible option. However, experience to date suggests that some NRM Regions in a better position manage the capacity building activities, while others are more likely to engage through the collaborative model building approach. This difference does not appear to be dependant on age or size of the regional bodies. The question as to whether to build collaborative models or capacity will continue to be explored in the remaining three years of this project.

## 1. INTRODUCTION

It is becoming more widely acknowledged that in order to appropriately support decision making and management with decision support systems (DSSs) and models, stakeholder participation is an important part of the DSS development process. Stakeholder participation is said to provide a greater level of ownership, self reliance and equitable outcomes (Hagmann et. al., 2002) and therefore increase the level of uptake (Phillips et al., 2003). The degree to which stakeholders are engaged in the development of such DSSs can vary from the elicitation of information which is then used to derive models, such as in the Mae Chaem example presented by Hare et al. (2003), to a more frequent participation and input into the DSS development process, such as in the Zurich example presented by Hare et al. (2003), the Coastal Lake Assessment and Management methodology (Ticehurst et al., 2007), or the NeWater approach (Henriksen and Barlebo, 2007). Lynam et. al. (2007) cautions that more participation is not necessarily better saying that different levels of engagement are appropriate for different cases.

Landscape Logic is a collaborative project that aims to assist the Natural Resource Management (NRM) Regions of Australia to better inform investment decisions, communicate decisions to their stakeholders while improving the condition of their natural resources (<http://www.landscapelogic.org.au/>). There are 13 partners within the landscape logic team including universities (ANU, RMIT and UTAS), State Government land management and research agencies (DPIW, Forestry Tasmania and DSE), research organisations (CSIRO) and 6 NRM regions, 3 in Victoria and 3 in Tasmania (see acknowledgements for a full list of partners). Prior experience and consensus amongst the project partners, including the focus NRM Regions, led to Bayesian networks being selected as the integration approach to be used in the project. The BN approach enables the documentation and modelling of the current assumptions between the decision to invest in a particular management activity and the expected natural resource outcome. New research being undertaken within the project will be combined with existing knowledge and understanding to inform the assumptions underlying the BN and therefore assist in the decision to invest in NRM.

The project partners met several times in the first 6 months of the project to identify focus issues for the BN development. Native vegetation condition and the management of water quality and flows

were selected from the environmental 'Matters for Target' common to the regional groups (Natural Resource Management Ministerial Council, 2003). It was initially proposed that the research group would develop BNs for the focus issues, in collaboration with the NRM Regions and research partners, and at the end of the project the NRM Regions would be trained in the use, development and maintenance of such tools. However, following an introduction into the BN process the NRM Regions expressed interest in being trained to develop BNs at the start of the project so they could construct their own to assist their planning, implementation, monitoring and reporting requirements.

Consequently two concurrent approaches to BN development are being carried out in this project, each with different levels of participation from stakeholder groups. The first is building capacity in the NRM Regions so they can construct their own BNs (*Capacity building*). The researchers' train the NRM regional staff in BN development and then provide supervision while they build their own. The second is the more widely used approach where the researcher develops the model with periodic review and input by the stakeholders (*Collaborative Model Building*).

The NRM Regions included in this project have similar objectives, but they have established different processes for decision-making. Their size and experience also differs with the Tasmanian Regions being 4-5 years old and smaller (10 staff versus 70 staff on average) than the Victorian regions which have been operating for over a decade. This inadvertently presents an opportunity to trial the success and adoption of the BNs using two levels of stakeholder engagement, and to compare the outcomes across NRM Regions and States on a small sample size. This paper discusses the findings to date as to the success of building models or capacity in this case.

## 2. METHOD

It is important to note that the investigation discussed in this paper is not one of the primary objectives for the Landscape Logic project so we have not actively sort to structure an experimental design to test the hypothesis as whether to build collaborative models or capacity. Instead this opportunity presented itself during the project development. Consequently the same NRM Regions are undergoing both the capacity building and model building components of the project, so it is possible that outcomes from one experience may impact upon the other.

The capacity building approach used for the NRM Regions to develop their own BNs consists of 3 main steps. Firstly each region was invited to send two or three representatives to a two day training workshop. The workshop held in March 2007 stepped through the theory in developing BNs, shown in Table 1, and each step was followed by hands-on experience putting the theory into practice. These trained representatives were to go back to their NRM Regions, transfer the knowledge they had learnt in the training where appropriate, and begin developing BNs to assist in their decision making processes. Two follow-up visits were planned for each region, the first being 2 months after the initial workshop (May 2007) and the next 3 months after that (5 months from the initial workshop, August 2007). One day was allocated to each region for each visit in order to assist them with the development of their BN and address any problems they may have encountered. In addition to the visits the trained representatives were encouraged to ask for additional assistance via phone and email contact, whenever they required it.

**Table 1.** The steps in developing a BN as they were presented in the training workshop.

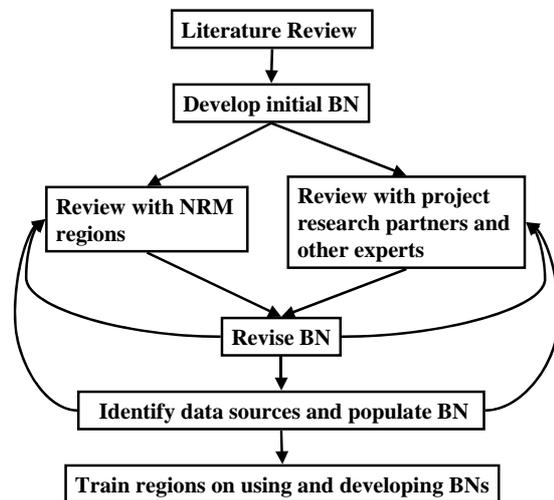
Step	Process description
1	Define focus issue and scale
2	Develop pictorial conceptual model
3	Develop influence diagram
4	Review influence diagram
5	Populate BN
6	Review and test BN
7	BN complete for scenario analysis

*NOTE: A BN should be reviewed and updated as new information becomes available, so steps 4 to 7 are iterative.*

The approach being used to develop BNs on the focus issues in collaboration with the project partners (*Collaborative Model Building*), is summarised in Figure 1. The project research partners, other experts and the NRM Regions are involved in reviewing the BN structure as it relates to their current decision making processes and assumptions, and to provide sources of data to inform the BN model.

Work to date has focused on building capacity within the NRM Regions although initial frameworks have been drafted for the collaboration BNs. A survey was completed by each of the participants following the March training workshop in order to gauge the impact and effectiveness of the training and their initial perceptions of how BNs will assist them in their decision process. A survey was also completed by

each of the participants in the follow-up visit 2 months later in order to identify whether BNs were still meeting their expectations, and what, if any, barriers they were encountering in developing these types of models. The results of these surveys, as well as anecdotal evidence are discussed with respect as to how effective capacity building within the NRM Regions has been to date.



**Figure 1.** Method used for generating building BNs in collaboration with the project partners.

### 3. RESULTS

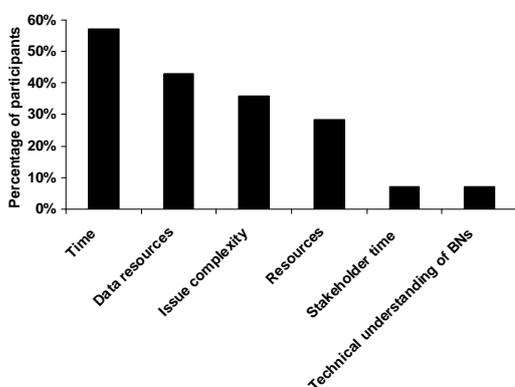
14 regional participants attended the March training workshop and completed a survey. 20 participants completed surveys during the May follow-up visit. Of the 20 participants who completed the second survey only 8 had attended the BN training and are referred to as ‘trained’ in the following discussion. This is only a small sample to test, so the results are only indicative. As there do not appear to be any differences between States (Victoria and Tasmania), the results are discussed for the group as a whole.

The NRM Regions have shown strong support for BNs to be used to assist in their decision-making processes, shown by their desire to be trained in BN development early in the project. The most likely reason for this response is that early in the project a demonstration of the function and relative ease of building BNs was given using the participant input and discussion. Crucial to this success was the availability of the software package (*Netica* <http://www.norsys.com/>) used to demonstrate the BN process. This was very user friendly, and within a short time capable of demonstrating its potential to capture current assumptions and uncertainty in the NRM decision-making environment. Henrikson and Barlebo (2007) report similar benefits from spending time

and resources to introduce stakeholders to the BN technique.

This support continued and following the March training workshop, 64% of the participants felt that BNs would be able to assist in decision-making in their organisation, while 36% were still undecided. No one felt that BNs would not assist in their decision-making.

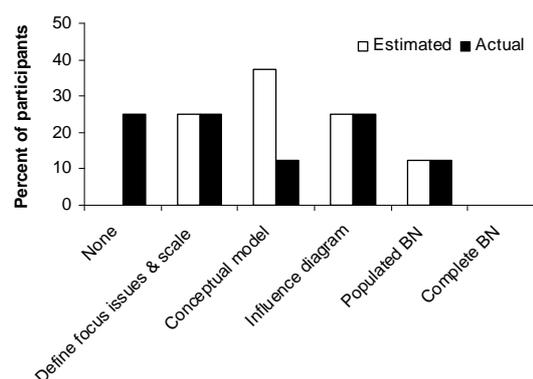
The BN approach to integration does not need to represent each process explicitly (Borsuk et. al., 2004) and is therefore very flexible to model over many temporal and spatial scales. Following the training workshop 36% of participants thought that the complexity of the issues they were trying to model was a limitation in using BNs within their organisation (Figure 2). After the May follow-up visit over 60% of the 'trained' participants had changed their BN focus issue to a large spatial scale, or a higher level of management, most likely in response to the perceived complexity in representing their prior processes in a BN. However the NRM Regions are still using BNs for narrow scale issues such as the management of a particular threatened species, as well as the broader scale strategic matters such as the interaction between their management actions (such as revegetation) and resource condition targets (such as water quality).



**Figure 2.** The key limitations as judged by the training workshop participants

The participants were asked what progress they thought they would have made by the May visit and what they have actually achieved. Most of the trained participants (38%) thought they would have completed a conceptual model by the 2 month follow-up visit (Figure 3, see also Table 1 step 3). However, only 12% answered that they had actually completed the conceptual model. This information is believed to be unreliable because upon our arrival the most progress that had been achieved by any region was a defined focus issue

and scale (Table 1, Step 1), not a conceptual model (Step 2), influence diagram (Step 3) or populated BN (Step 5) as the results in Figure 3 suggest. Some of the confusion is most likely due to participants answering that their actual progress was what had been achieved at the end of our follow-up visit, and not what they had completed on their own upon our arrival. Despite this inaccuracy, anecdotal evidence suggested that many of the regional staff had not progressed their BN development as they had anticipated, given that 25% had not made any progress at all (Figure 3).



**Figure 3.** 'Trained' participants estimated and actual progress in the development of BNs within the NRM Regions between the training workshop and 2 month follow-up visit.

Figure 2 shows that following the initial training, time (57% of participants) and data resources (43% of participants) were believed to be the most common limitations for participants to develop BNs within their organisations.

**Table 2.** Weighted average (Wt Av.) of the barrier rank (1 greatest to 7 smallest) for the trained and untrained participants to developing BNs.

Barrier rank	Trained	Wt Av.	Untrained	Wt Av.
Greatest barrier				
1	Time	1.1	Time	2.1
2	Stakeholders time	2.2	Stakeholders time	2.5
3	Data resources	3.3	Technical understanding of BNs	2.6
4	Technical understanding focus issue	3.6	Data resources	4.5
5	Technical understanding of BNs	4	Technical understanding focus issue	4.7
6	Additional support	5.8	Additional support	5.1
Smallest barrier				
7	Equipment and software	7	Equipment and software	5.5

At the May follow-up visit the NRM Regions were asked to rank the potential barriers to their BN progress given in Table 2, from the greatest (1) to the smallest (7) barrier. The weighted average of each barrier was used to rank the greatest barrier to BN development within the NRM Regions. It shows that time, both for regional staff and expert locals who would be expected to contribute to the process, are the greatest barriers to the NRM Regions developing their own BNs for both the trained and untrained participants.

Directly after the training, data resources was identified as the second most common limitation (Figure 2), and later it was again viewed as a high barrier to BN development with a weighted average of 3.3 and 4.5 by the trained and untrained participants, respectively. If there is a lack of data the BN process lends itself to utilizing expert opinion to provide some insight into the likely impacts being modelled. However, stakeholder time is identified as being an even greater barrier than the lack of data, thus emphasizing the time limitation on developing BNs, and presenting a cyclic problem. Additional support during BN development and the equipment and software were ranked as the smallest barriers to the BN development within the NRM Regions.

There is evidence that the training improved the regional staffs' understanding of BNs because the trained staff ranked the technical understanding of BNs as the fifth greatest barrier to their development, while the untrained participants ranked it as the third.

Despite these barriers to the NRM Regions developing their own BN they still see many benefits in the BN approach. These include that BNs:

- have a development process that aids discussion to clarify the issues, definitions and assumptions for the staff within a region,
- have a development process where the questions that need to be asked and answered are the same questions as is required in their current planning and management, and therefore they build upon the current processes rather than adding a new process or task,
- are useful for exploring and considering scenario options such as climate change and impacts such as economic costs in planning decisions,
- can be applied at a program scale to test whether resource condition targets are realistic, plan which set of investment

contributions are most likely to achieve the resource condition targets, and to target research and development and monitoring and evaluation to test assumptions in decision making,

- enable regional staff to document current understanding, assumptions and the broader decision-making process currently being used, information often contained only within the heads of regional staff [Note that this is important to retain corporate knowledge], and
- enable the NRM regions to illustrate to their investors and stakeholders the level of complexity they working within.

Some regional staff caution about the use of BNs because of the:

- trade-offs between complexity and usefulness,
- level of work required to complete a BN, and
- whether BNs will improve the quality of their current decision making processes.

Generally the NRM Regions believe that the benefits of BNs outweigh the barriers to their development as only 1 surveyed participant (5%) who had not been trained and had only been introduced to BNs during the May follow-up visit was still undecided as to whether it was feasible for the NRM Regions to develop their own BNs. The other 95% of participants still believed that the development of BNs by the NRM Regions themselves was feasible. Note these statistics do not account for some participants of one workshop who did not complete surveys, but noted some of the concerns listed above. So although there are some reservations about the usefulness of BNs to the NRM Regions it was clear that the vast majority of the regional staff still support the approach enough to continue their commitment to build their own capacity.

#### 4. DISCUSSION

This investigation into BN capacity building within NRM Regions has proven to be successful to date, if judged only by the regional support for the project. This is believed to be because of the effort made to introduce the potential end-users to the BN modelling process very early in the project. Additionally the nature of the BN development process, which relies upon the documentation and inclusion of stakeholder opinions, and the usability of the software, would have also played a key role in its appeal to the NRM Regions.

Flexibility is also crucial in order to be able to respond to the requests of the end-users. In this

project, our response to the NRM Regions requests to be trained early in the project is believed to have assisted in securing their support in the BN approach, and support for the project, despite the barriers and set-backs to their capacity building. This is expected to lead to a successful uptake of the model building approach, even if the effort to build capacity is undermined by the barriers.

If the capacity building was judged by the progress made by the NRM Regions in developing their own BNs then it would be considered to be much less successful. Feedback indicates that the time available for regional staff and stakeholders to contribute to BN development is the major barrier BN development within the NRM Regions. However, given that one of the benefits of the BN development process is that it “builds upon the NRM Regions processes” the regional staff believe they will still explore the development and use of BNs within their organisations, but that the development will take place over a period of many years as it fits in with other planning timelines. Originally the next follow-up visit for the capacity building component was scheduled for August 2007. But in order to accommodate the time lag in BN development, the variation between the NRM Regions’ resources and timing of planning activities necessary for BN development, the timing of the next regional visit remains flexible and will be offered to each region individually on request. This allows the NRM Regions to call for this additional assistance when they have made reasonable progress and could best utilise the help on offer.

If BN development extends over many years it can create another limitation in building capacity within the NRM Regions, because there is evidence of significant staff turnover in some regions so maintaining BN knowledge within a group may be difficult. Within the 4 months since the training workshop one of the 14 participants has left their respective region. On a related issue only 8 of the regional staff that were trained in the initial workshop were available to participate in the May follow-up visit, due to other work commitments. Initially, our role was perceived to be ‘people’ specific, working to develop the skills of key representatives from each NRM Region who would then complete the appropriate transfer of knowledge within their group, thus building the capacity. Staffing levels and turnover within the NRM Regions may mean that this is not possible, which limits our ability to build capacity within the NRM Regions as a whole.

The allocation of a new staff member to each region for a short period of time (e.g. 6 months)

with the sole purpose of developing BNs is one option to accelerate the capacity building while accommodating for the lack of staff time. Once a BN has been developed the existing staff would need only to update and maintain the BN, a less time consuming task. Most NRM Regions were very positive about having this sort of resource made available to them. Other NRM Regions seemed complacent about the idea, and were more resigned to the fact that there would be a large resource requirement in order to complete the initial BNs but that this short term investment would be worth it in the long term. One region seemed unconvinced that it would be a good idea to have an external person to develop the initial BNs in collaboration with the regional staff and then leave, because this risks the loss of some of the benefits of learning within the organization that the BN process has to offer. This approach would essentially move towards the model building approach already being undertaken in this project. This indicates that although the NRM Regions may support the idea of building capacity and their own models, the current staffing environment may make this option impractical for some.

One response to this is a coordinated approach to expert elicitation to minimise the time required by stakeholders to contribute to BNs and maximize the benefit to the NRM Regions from their time. This could be achieved by seeking expert input at a general level to ensure it would be more transferable from one region to another, and therefore the stakeholders would not have to attend multiple workshops for each of the NRM Regions. This may involve a trade off between specificity and transferability, resulting in more generic BNs dealing with general trends and impacts.

## 5. CONCLUSION

The Landscape Logic project (<http://www.landscapelogic.org.au>) inadvertently provides an opportunity to compare the success of two levels of stakeholder participation as it relates to the development of BNs. One is of building capacity where the stakeholders are trained and supervised through developing their own BNs (*Capacity building*), while the other is the collaborative approach where the stakeholder participation is used to structure, review and populate a BN being developed by the researcher (*Collaborative Model Building*). This project was not specifically designed to address this particular scientific question, so the results are a reflection of what lessons have been learnt to date from the opportunity that was presented.

Work to date has focused upon the capacity building approach in 6 of Australia's 56 NRM Regions, thus only a small sample. Results show that despite the significant level of support for the BN development by the NRM Regions themselves, they have been able to make only limited progress. The key barriers to BN development are the time available for both the NRM regional staff and the other stakeholders to provide input into the process. Flexibility in the capacity building activities will enable the NRM Regions to continue developing their BNs in parallel with their corresponding planning and reporting activities to maximise complementarity of effort and limit the additional work load. However, staff turn over in the NRM Regions may undermine the capacity building if it takes place over too long a period. Allocating an additional staff member to each NRM Region to accelerate the initial BN development could address the issue of losing BN capacity with staff turnover, but this approach could remove some of the organisational learning benefits of the BN development process. This approach is very similar to the model building process which is also being used in this project.

It is still too soon to answer the question as to whether we should build collaborative models or capacity in order to assist the NRM Regions target their investments using BNs, as only one year of the four year project have been completed. However, despite the significant support of all the NRM Regions to the BN approach it appears that some are more likely to manage the capacity building activities, while others would receive greater benefit from the model building or collaboration approach. This investigation will continue throughout the life of this project.

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