Continuous noise monitoring network design: an end user perspective

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ABSTRACT

Continuous Noise Monitoring (CNM) systems are commonly utilised to assist in the remote assessment of noise impacts associated with industrial complexes. In Australia, these systems have benefited significantly from rapid innovation in technology and wireless communication networks in the last 20 years, and now collect vast quantities of data that may be used in near real time or stored for later processing. In some sectors, the speed of this innovation and rapid uptake of new technology has outpaced the development of training and education tools that adequately equip end users with the ability to transform this data into useful information. A survey of Environmental and Community managers was undertaken to explore how CNM Systems are used to assist in the management of environmental noise impacts in the NSW mining sector. The survey sought to understand the various objectives of continuous noise monitoring, identify constraints and opportunities, and provide for self-assessment of end user competencies. The outcomes of this study contribute to narrowing of the knowledge gap between users and suppliers of environmental management technology, and furnish stakeholders with information to improve the utility of CNM Networks.

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1. INTRODUCTION

Rapid advances in computing and communications technologies have fostered an emerging expectation of, and capabilities for use of Continuous Noise Monitoring (CNM) within the environmental management setting. During the 2005 to 2008 Australian resources boom these technologies were widely adopted within the mining sector to assist with the management of noise impacts. While these technological innovations provide environmental managers with unprecedented access to a range of noise monitoring data, the pace of this development has significantly exceeded capacity of scientists, policy makers or end users to develop measurement standards or regulation that seek to guide the collection and use of this data.

Historically, industrial noise in Australia has been managed through development and implementation of some form of a Noise Management Plan (NMP). The NMP typically establishes requirements for measurement of any noise generated by the industrial activity, and this is the primary mechanism by which feedback on environmental noise impacts are obtained. In developing the NMP, the location and frequency with which these measurements are undertaken is of critical importance, as these decisions significantly influence the ability of the NMP to discriminate between project specific, and extraneous noise contributions in adjacent receiving environments, or across its network of monitoring locations. Reliable access to accurate and representative feedback on project specific contributions is vital to allow for effective monitoring and response to potential adverse impacts.

Prior to the development of continuous (and remote) monitoring technologies, impacts associated with large scale industrial developments have been monitored (and therefore managed) using established practices built around operator attended measurement. Having an operator in attendance at the time of the measurement provides flexibility, allows for active experimental design to be introduced into any monitoring plan, and therefore provides some contingency for quantification of any unexpected contribution from extraneous noise sources.

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While capabilities have progressed rapidly in the past decade, continued difficulties in the development of methods to reliably validate source contributions have restricted the ability of CNM Systems to play a greater role in the noise management feedback loop. Issues' relating to source validation means that the widespread use of these systems is typically limited to a form of parallel monitoring that relies on validation from the incumbent operator attended assessment practices.

While this barrier to the increased utility of CNM systems is commonly identified by all levels of stakeholders, the prevailing view focuses on the limitations on the CNM Systems, and not the opportunities that Networks of CNM Systems may provide to overcome these challenges. CNM Systems typically utilize similar measurement hardware, and hence observe similar noise data types as may be obtained during operator attended monitoring. When considered in this context, it may be reasoned that the perceived strength of operator attended monitoring lies not in the measurement method and data obtained, but in its transience, flexibility and ability to actively exclude extraneous contributions.

Following this, it is considered that it is not the measurement methods or instrumentation that currently limit the capabilities of CNM Systems, but the 'passive' monitoring regimes that are typically applied. While the fixed infrastructure of unattended CNM Systems dictates that a level of real-time flexibility commensurate with operator attended approaches cannot be reasonably met, any efforts to reduce the passivity of the CNM Network design would allow for more active exclusion of extraneous source contributions, and foster improvements to the capabilities of CNM.

To understand how this process may already be taking place, and to document existing barriers, a survey of Environmental Managers in the NSW and Queensland coal industry was undertaken. The survey sought to explore how CNM is currently used, what differentiation is made between applications (or limitations of) CNM Systems and Networks, understand the various objectives for establishing CNM as part of a management strategy, and identify any opportunities that these stakeholders consider relevant to future capability development.

2. Methodology

2.1 Outline Methodology

A series of questions relating to the use of CNM was prepared to explore the ways in which these technologies are used as a management tool the mining sector. The questions were framed within a short survey that sought to obtain a range of qualitative and qualitative data about the configuration, implementation and objectives for use of CNM. While the survey was specific to the mining sector, the intent of the research was to explore the use of CNM for the purposes of furnishing end users, regulators and community stakeholders with an outline of the state of contemporary CNM practices.

To achieve this outcome, the study considered CNM in the context of both CNM Systems and CNM Networks. Questions relating to the configuration of individual CNM Systems were included to understand how technological and data analysis approaches may be contributing to management capabilities. Questions relating to the configuration of CNM Networks and uses of supporting data (such as meteorological, predictive modelling or operational monitoring) were included to understand how experimental design approaches are being utilized to control for extraneous source impacts.

2.2 Survey Respondents and Distribution

Participants for the survey were identified through their patronage to existing professional networks and industry groups. To ensure a base level of participation, respondents were initially recruited through previous working relationships; to maximize responses from a larger cross section of Environmental Managers in the NSW coal sector, an open invitation was also extended to members of the Hunter Coal Environment Group (HCEG).

Any individuals that expressed interest were contacted directly via phone to discuss the scope and commitments of participation the study. In total, 25 participants were recruited, and copies of the survey were issued to each of these individuals via email. Following its issue, participants were given approximately 10 days to complete the survey.

2.3 Survey Questions

The survey was constructed around four main themes of questioning. As outlined below, these themes sought to explore various aspects of CNM Systems and CNM Networks, and obtain a mixture of qualitative and quantitative data.

2.3.1 Theme 1: Configuration of Monitoring Systems and Networks

Respondents were asked to identify the number of individual systems (or monitoring locations) that comprise the CNM Network under their control. Questions relating to the use each CNM System in this network were posed to document the range of specific purposes for which monitoring may be undertaken. These questions related to identification of the primary monitoring objective of each CNM System, its location in the Network (within the mining lease or on privately owned property), what supplementary (e.g. meteorological) monitoring may be undertaken to support interpretation of measurement data, and what level of constraints analysis was undertaken in the decision to site each monitor at its resident location.

2.3.2 Theme 2: Network Uses and Objectives

This line of questioning sought to explore the intended function of the CNM Network, identify the purpose for its use (or understand the relative importance of management priorities where the network seeks to address multiple objectives), and understand the extent to which noise impacts may require management intervention.

2.3.3 Theme 3: Data Integration and Reporting

Questions relating to the use or integration of contextual data were posed as a means of exploring the extent to which non-noise data sets (such as operational or meteorological monitoring) are actively used to assist in interpretation of noise monitoring results. Additional questions were also asked to understand the frequency, and methods by which data observed by CNMN are analysed and reported to various internal (and / or external) stakeholders.

2.3.4 Theme 4: Reflections on Network Design

This series of questions sought to obtain subjective responses relating to opportunities and constraints associated with CNM, and perceptions about its role in the management of industrial noise impacts. In an effort to contextualize these responses, each respondent was offered the opportunity to provide a self-assessment of ‘noise management’ competencies for both themselves and colleagues within the operation in which they work. As an addendum to this question, they were also asked to identify specific tasks or challenges for which they would typically seek external technical assistance. The final question was voluntary, and sought to obtain identifying information about the respondent and their operation, to enable further investigation.

2.4 Data Analysis and Reporting of Results

The objective of the study was to explore the various ways in which CNM is used within the mining sector, to evaluate where stakeholders may require further technical support to maximize the utility of these management tools. Given the relatively small cohort and exploratory nature of the investigation, complex statistical analysis was not considered appropriate (and questions were not designed to support such analysis). Instead (where possible), questions were structured to enable direct reporting of results, or simple exploration and review of responses was undertaken to identify recurring themes.

3. Results

The survey was issued to 25 participants in the NSW and Queensland mining sector, and 13 responses were returned at the end of the survey period. As identifying information was only returned by a small number of respondents, it may only be assumed that each response represents data about the way that CNM are used at 13 different operations (i.e. duplicate responses from the same operation were not returned). Relevant results for individual questions are reported in Sections 3.1 to 3.5. To assist in interpreting these results and understand who is typically responsible for CNM systems, an outline of the role of each of the respondents (in their organization) is provided in Table 1.

Table 1 – Role of responding participants

Role in Organisation	Number of Responses	Portion of Responses
Env or Eng Graduate	2	15%
Env Advisor / Officer	4	31%
Snr Env Advisor / Officer	4	31%
Site Env Manager	2	15%
Operations or Production Manager	0	0%
Complex Env Manager	1	8%
Group Env Manager	0	0%
Contractor / Consultant	0	0%

3.1 Location and uses of individual CNM Systems (Theme 1)

Across the 13 operations, responses indicate that 8 operations reported use of a single CNM System, and the remaining five operations reported using 2, 3, 4, 5, and 6 CNMN Systems respectively. In reporting this result it is acknowledged that the quality of responses is questionable, as review of NMPs (of respondents that did identify their operation) suggests inconsistencies in the reported number of CNM Systems.

While the veracity of these results are questionable, results that lend themselves to reporting on the basis of relative values (e.g. proportions of a total) are presented to salvage some of these data on system configuration, and establish some level of inventory of CNM uses.

Respondents reported that local meteorological monitoring is undertaken at a high proportion of locations (82%) to support validation of measured noise levels. Rates of validation using regional meteorological monitoring (e.g. an on-site 10m tower) were relatively lower (57%). Further results presented in Table 2 provide assessment of the configuration characteristics of CNM Systems and Networks that are used to monitor industrial noise impacts.

Table 2 – CNM configurations

Design Aspect	Characteristic of CNM System or Monitoring Location	Proportion of Systems
Monitoring location	Used as a reference monitor	43%
	Centrally located to represent impacts at a group of receivers	61%
	Concessions around access were made in siting of CNM Systems	4%
	Used to monitor cumulative mining impacts	14%
	Measure noise levels directly at site of complaint	43%
	Affected by extraneous noise, but a commitment to monitor there was made and monitoring location cannot reasonably be relocated	11%
	Affected by extraneous noise, but no better monitoring location identified	32%
	This system had been relocated at some stage to reduce extraneous noise contributions	18%

Measurement configuration	No method (e.g. total noise used)	14%
	Band-pass Filter	79%
	Directional noise monitoring	57%
	Statistical descriptors	64%
	Combination filters (e.g. band-pass and statistical)	18%

Review of these results indicates that there were various user interpretations of this question, as the summation of responses exceeds 100%. While the results may not accurately represent the proportion of different methods that are utilised, they do suggest that end users are implementing a number of different measures to discriminate between extraneous noise, and contributions from the source under investigation. Furthermore, results indicate that almost 20% of systems have been relocated at some point in their life to reduce exposure to extraneous noise sources.

3.2 Primary function of the CNM Network (Theme 2)

An outline of 9 possible objectives for use of CNM were provided, and the respondent was asked to consider these objectives, and rank from highest to lowest priority as they apply to CNM at their site. A numerical score was returned for each objective within each operation, and the results matrix was analysed by ranking from the lowest scoring objective (mostly priority #1) to the highest scoring objective (mostly scoring priority #9). The results are provided in Table 3.

Table 3 – Relative importance of CNM objectives

Rank	Objective
1	To obtain monitoring results that may be used to evaluate performance of management measures against objectives of NMP
2	Real-time management via reactive protocols (e.g. SMS alarming)
3	To assist in management of, or response to noise complaints
4 (equal)	To satisfy EA commitment, but system(s) are surplus to requirements
4 (equal)	To obtain baseline data or characterise ambient conditions
6	To act as a community engagement tool or manage social license
7	To assist in evaluation of longitudinal changes
8	Real-time management via proactive protocols (e.g. meteorological forecasting)
9	Other

Review of these results indicates that CNM is typically used to address objectives that relate to performance and real time management of noise impacts and complaints.

3.3 How significant an issue is noise management? (Theme 2)

The Environmental Managers surveyed as part of this study are typically charged with the management of a variety of environmental impacts – of which noise is one. This question was asked to explore the relative significance of noise management challenges, and provide some context to responses relating to use of CNM. The results provided in Table 4 indicate that noise management represents a significant challenge to the majority of mining operations, most of the time. No respondents identified a scenario in which noise management was not an issue of importance.

Table 4 – Relative importance of noise management

Importance	Responses
It is the biggest environmental management issue on our site	8%
It is in the Top 3 issues, all of the time	68%
It is in the Top 3 issues, but only at certain times of the year	8%
It is a minor issue, but monitored proactively	8%
It is a minor issue and can be managed reactively	8%
Noise is not an issue on our site	0%

3.4 Use of supporting data (Theme 3)

Several questions were asked to explore the types of data and methods that are used to validate or qualify noise monitoring data. Analysis of these responses is provided in Table 5and Table 6.

Table 5 –Methods for assessing temperature inversion strength

Assessment Method[1]	Responses
Direct measurement over interval > 50m (tower)	8%
Direct measurement over interval > 50m (natural topography)	8%
Inferred on basis of Sigma-theta method (horizontal wind variability)	69%
Inferred on basis of Turner method cloud cover and cloud ceiling)	0%
Inferred on basis of Pasquill-Gifford method cloud cover)	0%
No response provided	15%

Note 1: Assessment methods as outlined in the NSW Industrial Noise Policy

Table 6 - Use of non-noise data to provide context to CNM results

Data Type	Responses
Operational monitoring (e.g. fleet or plant state monitoring)	69%
Meteorological monitoring (to validate results)	92%
Meteorological forecasting (to assist in proactive or short term planning)	38%
Attended monitoring to validate CNM results	92%
Predictive modelling integrated in validation process	38%

3.5 Reporting and distribution of monitoring results (Theme 3)

Questions relating to reporting were included to understand the extent that information sharing or knowledge about management performance is distributed within the organization, or to external stakeholders. Assessment of these results is provided in Table 7. Due to observed variability in completeness of responses, the number of positive responses on which the result is based is reported to provide context.

Table 7 - Distribution of results from CNM

Reporting Type and Stakeholders	Responses
Raw results in near / real time or daily summary to operations staff (n=12)	92%
In summary form for internal environmental performance reporting (n=13)	77%
In summary form to promote workforce engagement, and provide feedback to staff on performance of management measures (n=13)	77%
In longer summary form for internal production performance reporting (n=10)	50%
In summary form to regulators (on a regular basis) (n=13)	69%
In summary form for public reporting (n=12)	50%
Reporting to regulators or public only takes place in response to formal request, or in response to specific event (e.g. complaint) (n=11)	55%

3.6 Reflection on End User Capabilities

Several questions were asked to explore the capabilities of the respondents and their peers (within the organization), and understand at what point of complexity they might defer to an external contractor or consultant for expert guidance. The results of this assessment outlined in Figure 1 indicate that respondents perceive themselves to possess a high level of acoustical literacy, with more than half reporting sufficient confidence to design and implement an effective NMP that utilizes CNM.

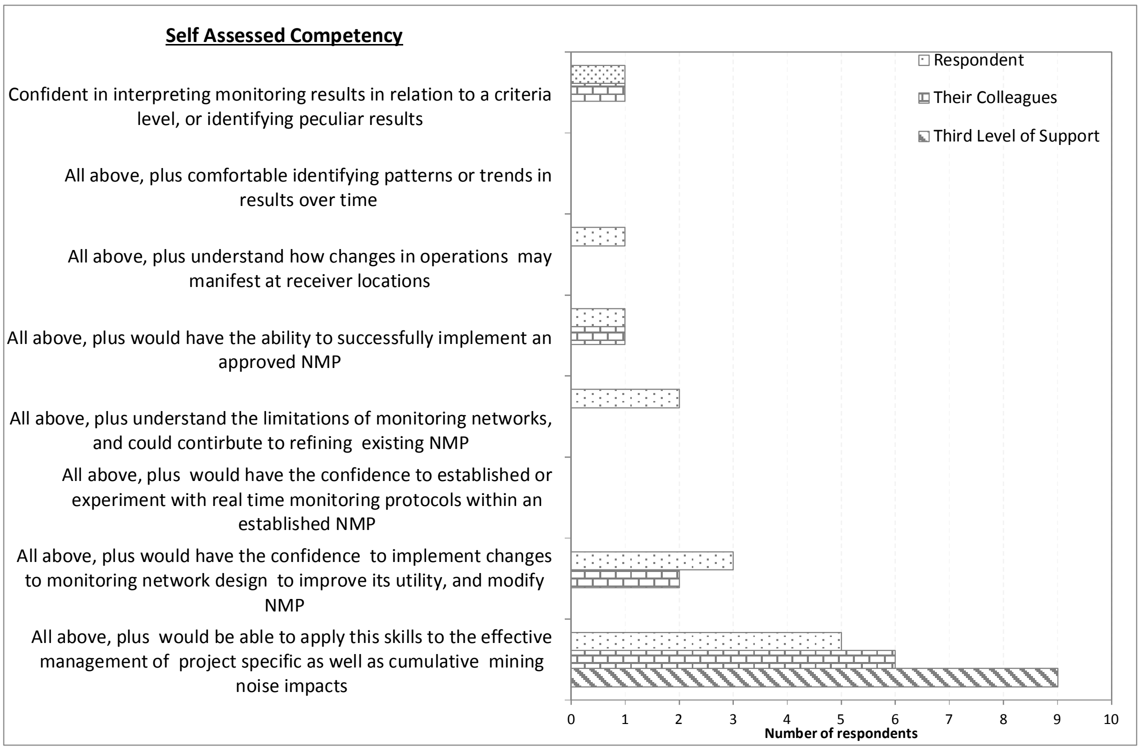

Figure 1 – Self assessment of respondent's competency

3.7 Reflections of CNM Network Design (Theme 4)

The final theme in the survey introduced a series of open questions (allowing for free text responses) to explore end user perceptions about the challenges and opportunities of CNM. These questions do not lend themselves to quantitative analysis; instead this feedback is reviewed in the discussion to provide further context to the reported results.

4. Discussion

Review of survey results indicates that there areas of uncertainty, but also commitment to continuous improvement of the ways in which CNM Systems and Networks are used. The results support the prevailing view that CNM is constrained by current capacities to validate significant amounts of data with high levels of confidence.

The results also demonstrate that a variety of methods exist to assist in validation (contextual, meteorological and operational monitoring); however, methods with the highest level of uptake are those that would have typically been used to support validation of operator attended measurement. While this suggests that true integration of data from disparate monitoring systems (e.g. predictive modelling and operational or fleet monitoring) does not represent widespread practice, approximately half (38% to 69%) of respondents reported using these more progressive methods in some capacity.

The bias towards ongoing use of existing historical practices is also observed in the distribution of reported meteorological monitoring methods (specifically temperature inversion). The majority of operations reported either reliance on interpolation of temperature inversion strength (sigma-theta method), or did not undertake inversion monitoring at all. A small number of operations (16% of the sample) reported using methods to directly measure the inversion strength in the bottom 100m of the atmosphere.

While interpolative methods are supported by regulators (and strong evidence exists to support their use), these methods return data only in terms of ‘categories’ of atmospheric stability. This ‘category’ data type typically provides sufficient information to assist with interpretation of a single operator attended noise measurement. However, in the same way that assessment of (for example) wind speed effects on continuous noise monitoring results would not be sufficiently served by assessment in terms of ‘wind speed classes’, validation of continuously acquired noise monitoring data would be better supported by a continuously acquired ‘non-categorical’ meteorological data set. Direct measurement appears to be one option that is gaining traction in the mining sector.

Review of results pertaining to System and Network configurations (Table 2) indicates that the dominant methods of using CNM Systems is in response to noise complaints (43% of Systems), and that a preference for monitoring directly at the site of perceived impact exists (62%). Despite this preference, respondents reported that a third of these Systems (32%) are impacted by extraneous noise contributions. For a further 10% of Systems it is acknowledged that they are highly effected by extraneous noise, but a commitment has been made (with either regulators or community stakeholders) to undertake direct measurement at that location, and despite the difficulty in validating these results, the system cannot be reasonably be relocated.

These findings suggest that a preference for direct measurement at the site of complaint is prioritized above a desire to establish an effective monitoring design to control (as far as possible) for extraneous source contributions, and thus obtain the best data possible to evaluate the legitimacy of the complaint. On this basis, the results presented in Table 2, suggest that 42% of CNM infrastructure (4 out of 10 Systems) is underutilized (as they require extensive validation of results) because poor consideration is given to design of monitoring programs that address specific management objectives.

Review of responses relating to various management objectives (Table 3) indicates that the most highly prioritized monitoring objectives (performance assessment, real time monitoring and complaints management) appear to correlate with the reported uses and configurations of monitoring networks. However, this correlation does not imply that managers are achieving a satisfactory outcome of these monitoring regimes, and comments that were received in relation to the performance of Systems and Networks supports this idea.

Nine (9) respondents noted some limitation of the existing CNM Network design, although review of free text comments suggests that some of these issues (raised by 4 respondents) relate to the performance of the CNM System (e.g. communication issues, band-pass filtering), rather than the Network.

Three (3) respondents did observe that there are Network limitations caused by exposure of some CNM Systems to extraneous noise sources (e.g. road noise), that may be improved by identification of better reference points. One respondent (1) also observed that use of a single CNM System on a rotating roster of multiple locations did present limitations, but implementation of additional systems would be surplus to management needs.

Six (6) respondents noted limitations with current CNM Systems, however their responses indicate that the limitations (relating to source discrimination and exclusion) are being addressed via continuous improvement practices to refine system configuration based on growing knowledge about use of those systems in those receiving environments. One respondent observed that development of alternative measurement descriptors (option for statistical results on band-pass filters) would be considered useful.

Despite these perceived challenges in using CNM, review of results presented in **Table 2** indicates that a commitment to continuous improvement is observed, as 1 in 5 (18%) of Systems have been relocated at some point in their life to improve the utility of the data they observe. Providing context to this result, 12 free text responses pertaining to the factors that may influence a decision to relocate (or identify a new) a monitoring location were provided. Seven (7) respondents noted that issues around access would be a primary factor in this decision, and reference to site suitability was made by only 1 respondent.

This indicates that, while end users appear content to address site specific CNM challenges via iterative changes to monitoring Network configuration, the factors influencing decisions about the changes to Network design relate more to managing access challenges than identifying and addressing site specific factors that may constrain monitoring outcomes.

While it is acknowledged that access represents a significant constraint to the design of any monitoring network, the weighting that this factor is given in the monitoring design and decision making process may have potentially significant impacts on future development and improvement of CNM. Review of results presented in Figure 1 indicates that more than half (61%) of respondents consider that they or their colleagues possess sufficient skills and confidence in their abilities to design an effective CNM monitoring program as part of a NMP. While all respondents indicated that they would defer to some source of expert advice (e.g. a consultant or contractor) to deal with the most complex problems, this result suggests a tendency to make decisions about Network design in house, and potentially incorrectly weight various constraints in that decision making process. While this may address site or activity specific challenges in the short term, it is unlikely to contribute to structural improvement in the use of CNM.

Despite the observed constraints and limitations, 12 respondents indicated that (in a general and reflective sense), CNM was considered to be a useful management tool. Several respondents acknowledged that management of CNM Systems can present a constraint in the short term (in terms of either direct constraints on production, or indirect pressures via introduction of new management overheads); however, these responses also recognized that CNM represents a great opportunity to identify noise impacts, understand how they can be managed, and provide additional motivation to remain in compliance. One (1) respondent commented that CNM is *"[sic] a constraint for production, but extremely valuable from the point of view of the reputation of the operation in the community"*.

5. Conclusions

Almost all responses qualified that while there were significant benefits to CNM, further integration in management systems was contingent on the capacity for recognized limitations to be addressed. Given that almost 85% of respondents reported that noise impacts are in the top 3 environmental management issues in their operations, it is hoped that this research contributes to better understanding of these limitations, such that scientist, policy makers and end users can work together to improve the utility of these noise management tools.

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