Asia-Pacific
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Comparison of International Frameworks Measuring Remotely Piloted Aircraft Noise
Final Report

APEC Transportation Working Group

September 2023

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APEC Project: TPT 01 2021A

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EXECUTIVE SUMMARY

The Comparison of International Frameworks measuring Remotely Piloted Aircraft (RPA) Noise Project aims to identify best practices and innovative solutions for measuring and regulating RPA noise. This culminates in a proposed framework.

This final report provides an aggregated collection of the project findings, outlines best practices for consideration by APEC economies, and communicates identified risks, issues, and opportunities for regulators and industry. These findings and insights inform the proposed RPA noise management framework at the end of the report.

APEC defined the scope of this project to evaluate existing and accessible items relevant to APEC economies that impact RPA.

HARMONISATION

Harmonisation across APEC economies enables similarities to be created, which provides opportunities for sharing knowledge, best practice, and conducting operations more easily between multiple economies. Whilst contextual differences are recognised, parallels, and therefore harmonisation can be found in expectations, definitions, and experiences of managing RPA noise.

Table 1 provides a glossary of key terms that are used throughout this project.

Table 1 Key terms

Key Term	Definition
Framework	A basic conceptional structure that provides underlying support for the intended outcome
Issue	An issue is an obstacle or challenge that's already present.
Management	Management refers to the overall practice of assessing and addressing
Mitigation	Mitigation is the reduction of something harmful or the reduction of its harmful effects
Noise	Unwanted sound
Opportunity	Situation in which it is possible for something to be done
Risk	Concept to describe the likelihood of harmful consequences arising from the interaction of hazards, communities, and the environments.
RPA	Remotely Piloted Aircraft. An uncrewed aircraft that is piloted from a remote pilot station. An RPA is a remotely piloted aircraft, other than the following: • a balloon • a kite • a model aircraft

Fundamental expectations identified from consultation with stakeholders included:

- Safety for community and operators
- Not overregulating the space
- Not restricting new entrants to the sector, such as mandating expensive testing

DESKTOP RESEARCH

Desktop research was conducted to identify, and review published and accessible literature relevant to RPA noise, with a particular focus on community noise impacts. These findings were collated into the research summary report, providing an overview of noise principles, and a summary of challenges and opportunities relevant to RPA noise measurement and management.

CONSULTATION

Informed by the research, consultation tasks were undertaken to ascertain the scope and efficacy of current noise management measures, in addition to the impact and management of RPA noise in APEC economies. These tasks involved a survey, five online stakeholder consultations, and a formal stakeholder workshop. Participant inclusion was informed by a predefined list of APEC economy contacts, industry stakeholders who were specifically mentioned in earlier engagement activities, and participant distribution to other peers. Additional conversations were conducted with individual industry stakeholders to supplement the insight gained from the specified consultation tasks.

The survey was sent to APEC economies for completion and aimed to ascertain the scope and efficacy of existing noise management measures, the respective RPA environment in each economy, and any work completed or in progress relevant to the project. Using a combination of qualitative and quantitative questions, responses included both detailed responses and discreet responses, enabling insight from text responses and statistical summations.

Each of the five stakeholder consultation meetings focused on a particular topic. Four of the topics were identified in the initial research phase and validated within the survey, which included a request for expressions of interest across a range of topics. The fifth stakeholder consultation meeting was scoped as women only, to support the APEC approach of *"mainstreaming "gender" into APEC"* projects.[1]

A formal stakeholder workshop was held to present the findings and analysis of the research and consultation tasks and engage with those attending to provide feedback and further insight into RPA noise. Breakout rooms and small group activities were used to explore opinions and experiences across emergent themes in the project.

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[1] The APEC Policy Partnership on Women and the Economy and associated work including project guidelines, define gender as binary categories of men and women, being "*the socially constructed identity of women and men – such as norms, roles and relationships between women and men.*"
The Framework for Integration of Women in APEC defines gender mainstreaming *as "women and men having equitable access to, and benefit from society's resources, opportunities and rewards and equal participation in influencing what is valued and in shaping the directions and decisions" and "incorporating gender perspectives into the goals, priorities, policies, decisions, practices, activities (including projects) and resource allocation as well as participation at all levels."*

REGULATORY COMPARISON ACROSS APEC ECONOMIES

Each APEC economy has its own regulatory and policy parameters relevant to RPA noise, with some economies also having targeted RPA noise regulations. Figure 1 summarises the regulatory approaches used by APEC economies, that are publicly accessible, and shows the number of economies that use each specified approach.

The comparison of economy regulations relevant to RPA noise demonstrated:

- The majority of APEC economies differentiate between hobby and commercial RPA operators
- RPA registration is typically required, with more economies requiring it for commercial operations
- Australia is the only economy to have a specific complaint process for RPA noise
- Six of the 21 economies have RPA noise work in progress, or future work planned
- The majority of APEC economies have training or preparation requirements before the registration or licencing process
- Community engagement, prior to changes occurring, was not shown to be consistent across economies
- Nine of the 21 economies did not have an easily accessible or commonly understood process for general noise complaints

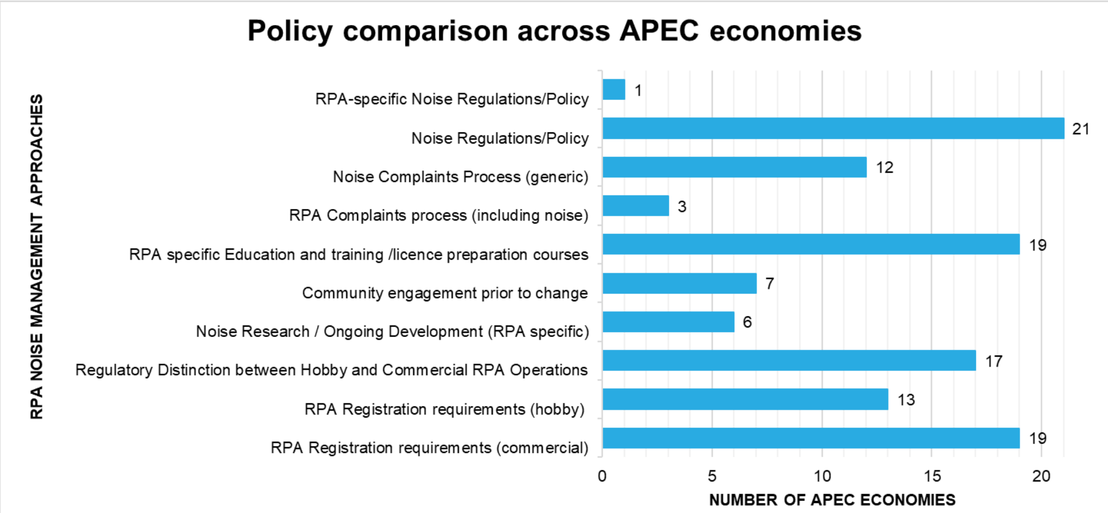

Figure 1 APEC economy policy comparison

RECOMMENDATIONS

This report communicates recommendations for regulators and industry and for consideration by APEC economies.

FOR REGULATORS AND INDUSTRY

Regulators are responsible for managing the existing policies and regulation, and those that it applies to. The industry is responsible for meeting these regulatory requirements, for operations and design. Both groups benefit if the current approach can be improved.

Technical approaches: Advances in RPA design and noise modelling can enable improved governance and more acceptable noise outputs.

Data sets: Engagement with shared databases of RPA noise data should support legislation and estimated noise outputs. This can enable initial verification of submitted data and understanding of the impacts of increased RPA operation in an area.

Engagement: Engagement and consultation approaches need to be considered for achieving and maintaining social licence

Data collection: Maintaining consistency and establishing best practice for RPA noise measurement can provide direction to those undertaking testing and allow fair information comparison. This includes approaches, validation, calibration, and equipment selection. It is also important to design the data collection to support the integration of data from other projects.

FOR APEC ECONOMIES

APEC economies are responsible for setting policies, passing laws, engaging in international forums, and financing initiatives where appropriate.

Improve governance: Lessons learnt from a review of existing noise governance can be utilised to develop a successful RPA noise management strategy and determine appropriate levels of governance, accountability, and responsibility. The future increase in scale and complexity should also be considered in the design of management approaches.

Engagement: Best practice is to engage stakeholders across the RPA lifecycle, including policy development, through to the complaints process.

Harmonisation: Engaging in international forums supports harmonisation through sharing knowledge to enable a consistent approach across jurisdictions and benefit from shared experience and learnings.

Financing: Implementing new governance can create a financial burden. To support increased adoption, funding or other incentives can support the creation, and transition of existing roles, and training for new approaches.

Understanding limitations: Awareness of the limitations of research when determining metrics for regulation is important to inform decision-making.

PROPOSED FRAMEWORK

The framework (Figure 2) is designed to meet the project objectives and the fundamental expectations identified throughout the consultation process. These objectives align with the following three categories:

1. **Purpose of framework: Advance economy capacity to manage RPA noise**
The framework provides the foundation for enhancing RPA noise management capability, through communicating knowledge and best practices, being outcomes-based, and highlighting components needing consideration in any management approach.

2. **Design of framework: Outcomes-based framework**
The outcomes-based framework helps to ensure that efforts are aligned towards achieving specific goals and objectives, and that progress towards these outcomes can be monitored and evaluated.

Each of the framework components is designed to achieve a defined outcome, aligned with the outcomes-based approach. These components work together towards achieving the overall aim of a safe and acceptable impact from RPA noise.

3. **Integration of framework outcomes: Global harmonisation**
The framework supports global harmonisation by providing a common language and approaches to achieve shared goals across different economies.

By focusing on specific outcomes and results, rather than prescriptive processes or regulations, an outcomes-based framework allows for flexibility and adaptation to local contexts while still ensuring the achievement of common goals.

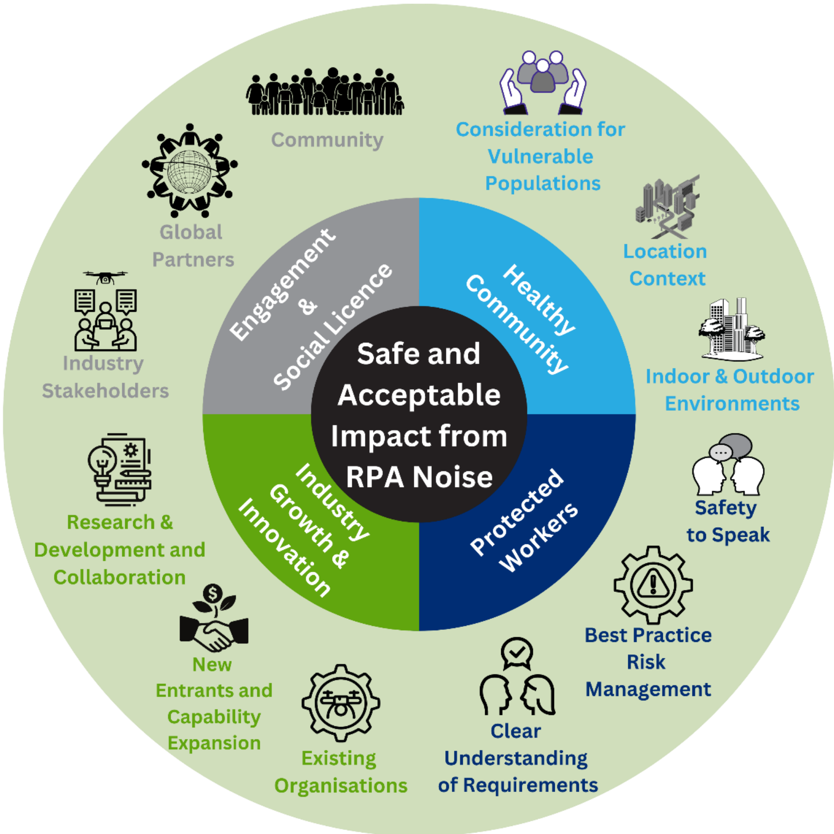

Figure 2 Proposed framework

ACKNOWLEDGEMENTS

The authors of this report wish to thank the numerous individuals and organisations who collaborated, participated, and provided input, to make this project possible.

To avoid unintentionally omitting any individual, contributors and stakeholders are thanked as part of the following categories:

- Staff from the Australian Department of Infrastructure, Transport, Regional Development, Communications, and the Arts, with particular mention to the Project Overseer Danika Thomas, and her colleagues, including Aleshia Currie and Sarah Lewis
- Members of the APEC secretariat, with particular mention to Clem Arlidge and Estella Ho
- Co-sponsoring economies:
  - Canada
  - Japan
  - New Zealand
  - The Philippines
  - Singapore
  - Chinese Taipei
  - Thailand
  - USA
- Participants in surveys, working groups, workshops
- Industry stakeholders
- Non-member economy participants

Mirragin RAS Consulting acknowledges the effort of organisations worldwide attempting to address the problems presented by RPA Noise. In many cases however, such work is being conducted outside of the APEC economy scope identified for this project. Despite the relevance of these undertakings, they have been deemed outside the scope of this report. For full harmonisation to be realised across all economies it is recommended APEC and organisations outside of the APEC contribute collaboratively towards a common goal.

INTRODUCTION

Remotely Piloted Aircraft (RPA) are being adopted globally, including within APEC economies. The breadth of applications provides many economic benefits; however, the uptake has raised concerns within communities about environmental noise.

Key issues with the regulation of RPA noise involve the continuous advancement of RPA technology, the perception of noise, flight mode and velocity operation, the environmental context and use-case.

PROJECT SUMMARY

The project objective is to enhance the capacity of all APEC economies concerning the management of noise impacts from RPA operations. This is to be achieved through the development of a noise management framework, and the dissemination of research.

- The framework will support increased harmonisation, mutual recognition and transferability of RPA noise measurements and approvals across economies.
- The research will compare approaches to the measurement, policy, procedures, and regulation of RPA noise in APEC economies and enable the identification of best practices and innovative solutions.

PROJECT RELEVANCE

Through consideration of existing operations, current work, and research that is relevant to APEC economies, this project provides economies with the foundational knowledge to support harmonisation in the development of RPA noise management approaches. This project will focus on several key areas to achieve this:

1. **Regulation and policy**

Noise regulation for conventionally crewed aircraft is based on international product certification and is used as the baseline understanding to inform RPA standards, despite not focusing on operations. There are currently no consistent international standards or frameworks for the measurement or regulation of RPA noise, and different economies are pursuing different approaches and frameworks in managing this emerging issue.

2. **Definitions**

Consistency in terminology, definitions, regulation, and certification will be beneficial to APEC economies.

3. **Social licence**

RPA emit an uncommon pitch which can attract attention and cause irritation and operate at much lower altitudes and in ways that are not possible for conventional aircraft (e.g., home deliveries). These issues present potential community noise impacts and may disrupt or irritate people in residential or urban settings, reducing the quality of life and acceptance of RPAs.

4. **Framework to encourage consistency**

By highlighting best practice and innovative solutions and encouraging international harmonisation, the project will support mutual recognition of RPA noise measurements across economies. This will reduce the regulatory burden for RPA operators and manufacturers and ensure noise measurement processes do not have to be repeated across economies, as is currently done for conventional aircraft.

5. **Common issues and best practice solutions**
All APEC economies are experiencing increased RPA operations and by identifying common issues and highlighting best practice solutions, the capacity for consistency and best practice response can be achieved.

PROJECT ALIGNMENT

This project was scoped to align and support the priorities of APEC economies and working groups.

Particular mention in project documentation was made to New Zealand's Policy Priorities for APEC 2021, which included 'Pursuing innovation and a digitally enabled recovery', 'Digitally enabled business and trade', and 'Structural reform to support innovation'. These priorities all align with the expanding application of RPA operations.

Additionally, the 2018-2020 Transportation Working Group Strategic Plan 'encouraged uptake and evaluation of technology development in the transportation sector through corresponding information exchange, and by complying with international standards to lead harmonious growth across the region'. This strategic direction aligns well with this project which aims to facilitate information exchange and contribute to the development of international standards for RPA noise management.

The project objective of disseminating knowledge around RPA noise management will support all APEC economies including developing economies, to take advantage of RPA to promote innovation in products, services, processes, organisations, and business models. Thereby aligning with the APEC Putrajaya Vision 2040 of promoting innovative technologies and economic integration, and the ASF (APEC Support Fund) General Fund funding priority of 'Facilitating technology flows and harnessing technologies for the future'.

PROJECT CONSTRAINTS

This report has been prepared by Mirragin RAS Consulting for the APEC RPA Noise project in conjunction with the Australian Department of Infrastructure, Transport, Regional Development, Communications and the Arts, and the co-sponsoring economies (Canada; Japan; New Zealand; The Philippines; Singapore; Chinese Taipei; Thailand; USA).

Mirragin has prepared the project work based on information provided by representatives from APEC economies and selected non-member participants. This information has not been independently verified or checked beyond the agreed scope of work. All APEC economies were encouraged by the APEC Secretariat to provide their input to this work. However, participation was voluntary and the level of engagement in activities (e.g., consultation meetings, or the workshop) and response rates to email requests for information or surveys were not within the control of the contracted consultancy.

The conclusions and recommendations have been based on information reviewed by the date of preparation of the report, including participant responses. Acknowledging that the area of RPA Noise is a rapidly evolving space, it is expected that the RPA Noise sector will quickly develop beyond what has been identified in this report. As such, this report should be read in the context of 2022 and 2023 RPA noise knowledge within APEC economies.

ASSUMPTIONS

This project has been based on the following assumptions:

1. APEC-nominated contacts are considered suitably representative of their respective economy and are best placed to discuss RPA Noise for their economy (unless an alternative contact was subsequently nominated).
2. Participants have provided accurate, complete, up-to-date, and relevant information for their economy.
3. Economy RPA noise information included in the project work has been reviewed by each respective economy, either in a consultative or reviewer capacity and all economies have had the opportunity to provide feedback if desired.

PROJECT SCOPE

The TPT 01 2021A ‘Comparison of International Frameworks Measuring Remotely Piloted Aircraft Noise’ project specified several deliverables to be completed within the APEC-designated timeframe and budget. The work undertaken by Mirragin in preparing the deliverables, including this report, is subject to the scope limitations set out in the contract.

The scope limitations for each of these services are shown in Table 2.

Table 2 Project service requirements

Service	Desktop Research	Consultation, Workshop and Summary Report	Interim Report	Final Report
Continuous Aim	• Identify RPA noise common risks, issues, opportunities, and best practice			
Aim	• Focus on community noise impacts • Inform the consultation process	• Ascertain the scope and efficacy of current noise management measures • Summarise common issues, challenges and opportunities identified during the consultation process	• Focus on the agreement of fundamental expectations, definitions, challenges, and regulatory/ policy parameters between APEC economies	• Develop a Noise Management and Community Noise Impact Mitigation Framework
Information source(s)	• Existing and accessible items relevant to APEC economies that impact RPA • Secondary research only – use of existing data and research	• Workshop participants (invited per APEC provided list) • Qualitative and quantitative analytical methodologies • Privacy and data collection limitations per economy	• Project work to date • Stakeholder feedback	• Project work to date • Stakeholder feedback
Deliverable	• Report: No more than 30 pages	• Report: No more than 30 pages	• Report: Approximately 60 to 100 pages	• Report: Approximately 60 to 100 pages
Collaboration	• Co-sponsoring economies invited to provide information (Canada; Japan; New Zealand; The Philippines; Singapore; Chinese Taipei; Thailand; USA)	• All APEC economies invited to participate in the survey, online stakeholder meetings, and workshop • Engagement with key industry stakeholders	• Australia's project team to review and provide feedback • Sought stakeholder feedback (from APEC economies and industry stakeholders) as appropriate	• Framework developed in consultation with Australia's project team • Report endorsed by APEC co-sponsoring economies

REPORT STRUCTURE AND FORMAT

STRUCTURE

The overall structure of this report includes an introductory section followed by four main content chapters (Research Summary, Consultation Summary, Recommendations, and Framework), and concludes with opportunities for future work and closing statements.

RESEARCH SUMMARY STRUCTURE

The Research Summary contains the Desktop Research Summary and a Comparison of Economy RPA Noise Regulations. These two sections are distinctly different and therefore, each has a separate reference list that pertains only to that section.

The Desktop Research Summary covers the generic principles of noise, noise impact, measurement techniques, and mitigation strategies, contextualised within RPA operations. It considers all publicly available literature.

The Comparison of Economy Regulations is concerned specifically with the APEC member economies, and the existence of comparable regulations or policies in force in each of these economies, that may have some relevance to RPA noise.

CONSULTATION SUMMARY STRUCTURE

The consultation summary chapter contains an overview of the Survey results and a thematically summarised summary of each of the stakeholder engagement meetings.

The Survey results are presented in figures and key trends observed from the analysis of the results are summarised thematically into tables where appropriate.

The stakeholder engagement meetings are summarised in a “meeting minutes” format, with one per discussion topic. The pertinent points raised during the discussions are grouped according to the emergent themes.

RECOMMENDATIONS

The recommendations provided are indicative of the lessons learnt by stakeholders who engaged in the discussion meetings or otherwise synthesised from relevant literature. These recommendations were used in the creation of the framework for RPA Noise Management and Mitigation.

Several areas worthy of a much more in-depth investigation were identified during this project, and they have been included in the non-exhaustive list of future work.

FRAMEWORK

The framework chapter contains an overview of the design rationale and the proposed framework with explanatory text.

FORMAT

STYLISTIC CHOICES

A significant portion of the work presented in this report is gathered into tables. This has been a deliberate attempt to group information in an easy-to-follow and somewhat self-contained way. Predominantly this occurs within a single theme where there are several sub-topics, but also in the case of listing risks and contrasting them with their related opportunity.

REFERENCING

The referencing style in use is IEEE which formats references with a number contained in square brackets (e.g., [1]). The number is determined by the order of appearance in the text, and IEEE style citations are provided in the reference list in this order.

Three separate reference lists are provided. They are distinct lists with negligible overlap. The first reference list contains all the cited works for the Desktop Research Summary section, the second reference list contains the sources used to create the Comparison of Economy Regulations tables, and the third reference list contains additional sources for the Framework development.

HARMONISATION

Harmonisation across APEC economies enables similarities to be created, which provides opportunities for sharing knowledge, best practice, and facilitates conducting operations across economy borders with ease. Whilst contextual differences are recognised, parallels and therefore harmonisation, can be found in expectations, definitions, and experiences of managing RPA noise.

FUNDAMENTAL EXPECTATIONS

Fundamental expectations identified from consultation with stakeholders included:

- The safety of both the community and operators is paramount
- Management approaches should be as minimal as possible (i.e., do not unnecessarily over-regulate)
- Respective regulations should have appropriately accessible means of demonstrating compliance (e.g., do not require expensive testing which could restrict new entrants to the sector)

DEFINITIONS

Key terms have been defined in Table 3 and Table 4, to provide clarity throughout project documents, and surrounding discussion.

ABBREVIATIONS

Table 3 Abbreviations of key terms

Term	Definition
APEC	Asia-Pacific Economic Cooperation
ICAO	International Civil Aviation Organization
g	Gram
Kg	Kilogram
m	Metre
RPA	Remotely Piloted Aircraft
RPAS	Remotely Piloted Aircraft System
UA	Uncrewed (Unmanned) Aircraft
UAS	Uncrewed (Unmanned) Aircraft System
UAV	Uncrewed (Unmanned) Aerial Vehicle

GLOSSARY

Table 4 Glossary of terms

Term	Definition
Duration	The length of time of noise exposure
Framework	A basic conceptional structure that provides underlying support for the intended outcome
Frequency	Number of pressure variations per second and units are described in Hertz (Hz). The normal range of hearing for a healthy young person extends from approximately 20Hz up to 20,000Hz (or 20kHz) Frequencies between 3000-4000Hz are most likely to damage human hearing
Hazard	A condition or object with the potential of causing injuries to personnel, damage to equipment or structures, loss of material, or reduction of ability to perform a prescribed function.
Impact	A marked effect or influence
Influence	The capacity to affect the character, development, or behaviour of someone or something, or the effect itself.
Intensity/ Loudness	This factor is measured by a noise level meter and the units are described in decibels (dB)
Issue	An issue is an obstacle or challenge that's already present.
Management	Management refers to the overall practice of assessing and addressing
Measurement	A determination of number or physical quantity, other than for descriptive purposes only
Mitigation	Mitigation is the reduction of something harmful or the reduction of its harmful effects
Noise	Unwanted sound
Opportunity	Situation in which it is possible for something to be done
Risk	Concept to describe the likelihood of harmful consequences arising from the interaction of hazards, communities, and the environments.
RPA	Remotely Piloted Aircraft. An uncrewed aircraft that is piloted from a remote pilot station. An RPA is a remotely piloted aircraft, other than the following: • a balloon • a kite • a model aircraft
RPAS	A remotely piloted aircraft, its associated remote pilot station(s), the required command and control links, and any other components as specified in the type design (ICAO, 2015).

STAKEHOLDERS

Stakeholders are a key component to the success of any management strategy.

This project consulted with:

- Representatives of all APEC economies
- RPA industry stakeholders[2]
- Non-member participants[3]

This project did not engage with any community stakeholders, but notes the importance of social licence and support and that the community should be considered more broadly than residents to recognise the various connections stakeholders can have[4]:

[2] A limited number of industry stakeholders were engaged for this project purpose, a wider sample should be consulted for specific economy application

[3] These participants typically received forwarded invites from colleagues

[4] Harrington et al. (2008)

DESKTOP RESEARCH ANALYSIS

The output of this phase was to identify common risks, issues, and opportunities to inform potential measurement and best practice measures for RPA noise management and mitigation of community noise impacts. The research approach is shown in Figure 3 and details the information sources used to inform the research.

This phase helped develop and refine questions and topics for consultation within APEC, which included issues such as acceptable volume, the impact of different altitudes of operation, and management of RPA noise and mitigation of community noise impact during different times of the day.

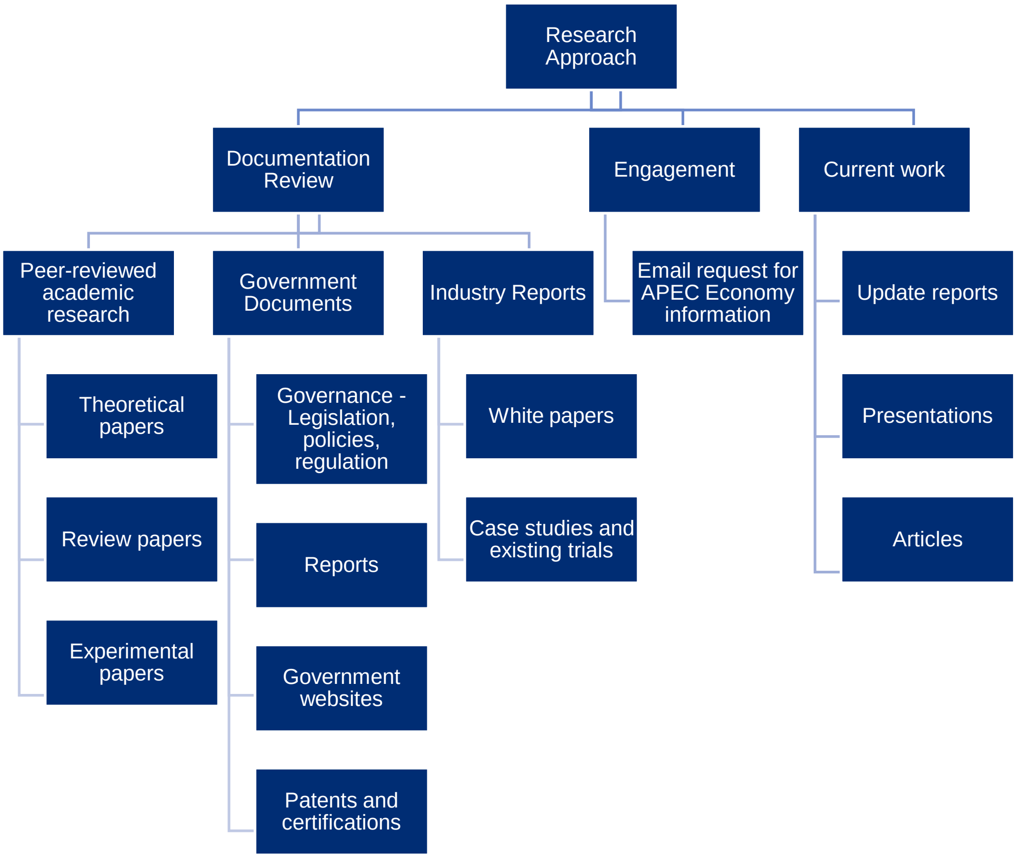

Figure 3 Desktop research information sources

NOISE PRINCIPLES

Noise is an unwanted sound experienced by the receiver. Sound is defined as a pressure variation that the human ear can detect [1]; however, frequencies that exist above and below the range of human hearing can still elicit a response. Sound travels through the propagating medium, such as air, in the form of a wave, and is impacted by a range of factors, such as objects, or the weather [2,3]. The sound is then heard by a receiver, and a response is created, as the receiver processes the sound information [1]. Figure 4 shows examples of sound sources across the typical sound range heard by the human ear.

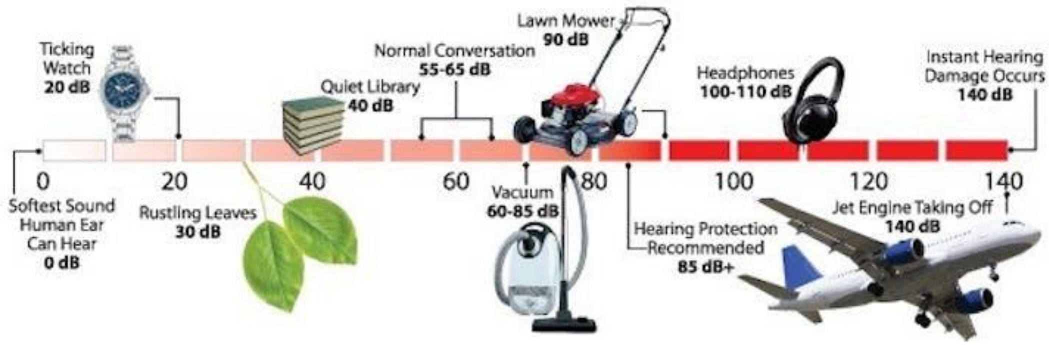

Figure 4 Scale of sound measurement [4]

As shown in Figure 5, the RPA generates noise that propagates to houses and people as it follows the flight path. Unlike traditional aircraft, RPA are not restricted to designated flight corridors, take-off and landing locations, or specific use cases, such as passenger aircraft. RPA also fly lower and are more likely to be operating in residential spaces supported by the commercial availability to hobby operators. Due to this freedom in the application, RPA are used in a wide range of operations, often conducted near people. The noise created during urban operation of RPA inherently impacts many people.

The air where RPA are most likely to be flown (in urban areas, close to the ground) is typically chaotic/messy (turbulent). RPA are more susceptible than traditional aircraft to atmospheric turbulence, and correcting for these small changes to flight conditions can cause audible fluctuations in the noise output.

In addition to the flight path and operating environment, the noise generated by RPA differs from that of traditional aircraft. This is due to a significant difference in design. The sound produced by an RPA because of these design choices is typically more tonal than traditional aircraft. Figure 6 shows the frequency and sound level difference between a fixed wing (traditional aircraft), a car and a multirotor RPA.

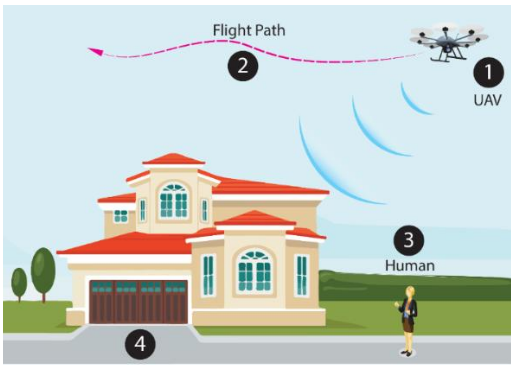

Figure 5 The acoustic problem [3]

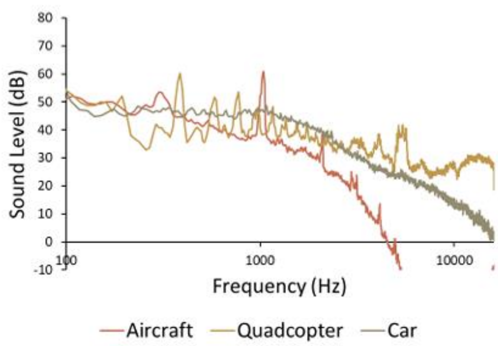

Figure 6 Frequency of a fixed wing aircraft, a car, and an RPA [5]

RPA NOISE SOURCE

Figure 7 shows potential contributors to the noise profile from a remotely piloted aircraft, with examples for each category. Each of these sources makes a different type of noise due to the shape and interaction with other components and the air and may contribute unequally to the overall RPA noise.

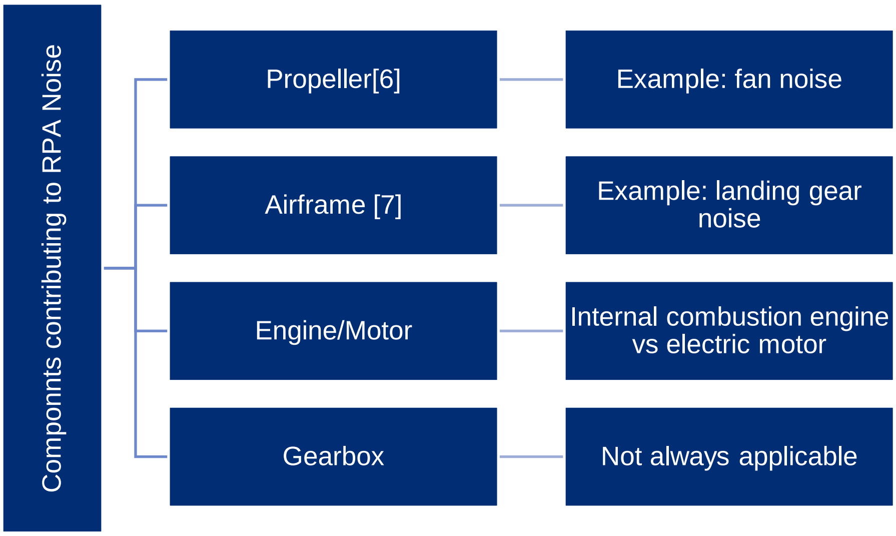

Figure 7 Components contributing to RPA Noise

RPA NOISE PROPAGATION

Figure 8 shows the key aspects which influence the propagation of sound (how the sound spreads) [1]. In addition to these aspects, the proximity to the noise source will influence the volume of noise heard and higher frequency sounds are likely to travel shorter distances.

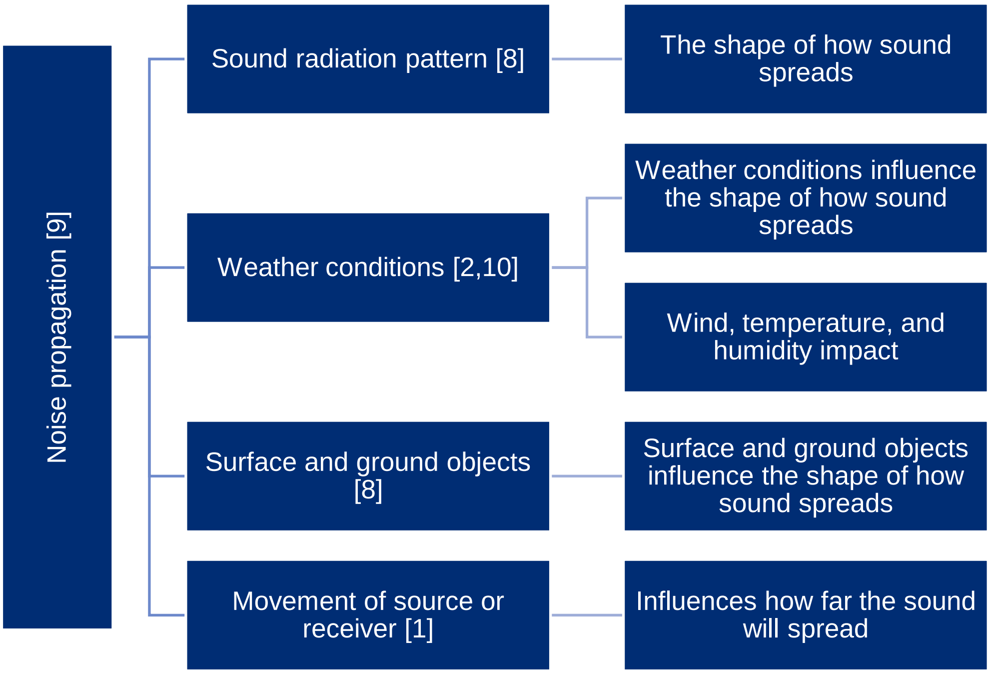

Figure 8 Noise propagation diagram

RPA NOISE RECEIVERS

"Aircraft noise is the most significant cause of adverse community reaction related to the operation and expansion of airports."[11]

Noise is received after it has been generated and propagated. Once received, it is either deflected, absorbed by a surface, or cognitively processed by the receiver. The cognitive processing of sound allows the creation of a conscious and/or sub-conscious response [12]. Aspects that impact this process are shown in Figure 9.

The impact of RPA noise on animals is out of scope for this project. However, it is noted that animal response anecdotally attributed to RPA noise can further impact the community. Examples include additional barking or disturbance to livestock [13]. Current evidence has not been sufficient to prove these impacts in the research [14].

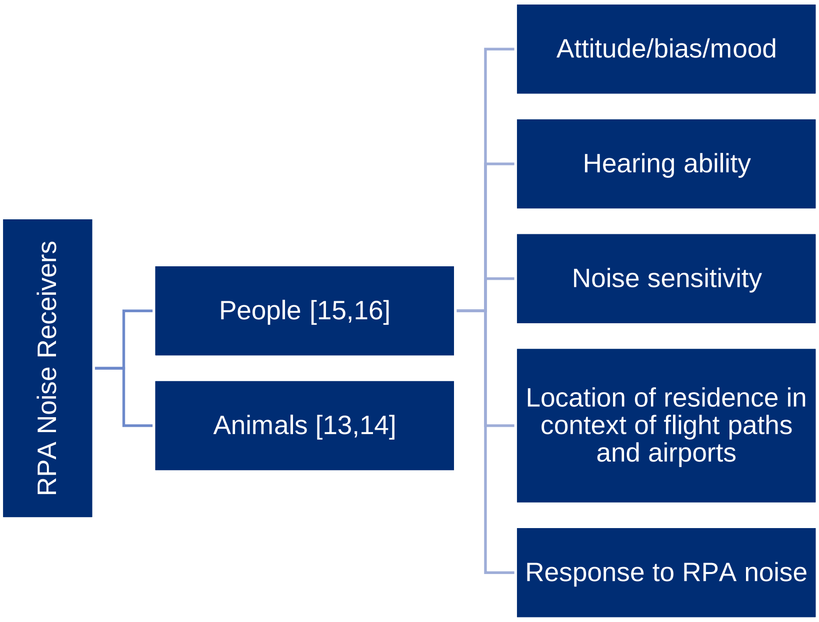

Figure 9 RPA noise receiver diagram

HAZARD TO COMMUNITY

Table 5 describes the hazards posed by noise to the community.

Table 5 Noise hazards

Hazard	Description
Dose	• The dose of noise is made up of intensity/loudness, number of events, and duration • Canada's Worksafe (OHSR 7.2) guidelines have limits for where sound levels exceed 85dBA Leq_8, or the peak noise exposure is greater than 140dBC.[17]
Low-frequency noise and infrasound	• Whilst low-frequency noise (10Hz-200Hz) below 85dBA is unlikely to cause physical hearing damage, it has been determined to cause psychological impact. [17,18] • People can still perceive infrasound (<20Hz) even if it is inaudible [19]

IMPACTS TO COMMUNITY

Table 6 lists some of the recognised impacts on the community caused by RPA or general aircraft noise as determined by the research. Anecdotal impacts are also acknowledged but excluded from the table. An example of an anecdotal impact is the death threats made to Project Wing in response to hearing delivery drones [20].

Table 6 Noise impacts

Impact	Description
Annoyance	• Annoyance is a common response to noise and has been widely researched [21] • Numerous factors have been and are being explored to identify what makes a noise annoying, however, responses can differ even from the same person, depending on additional factors [22,23,24]
Cancer	• Low quality evidence suggests a link between noise and some cancer outcomes [25]
Cardiovascular disease	• The World Health Organization (WHO) noted that there is good evidence between aircraft noise and cardiovascular disease [26]
Cognitive impairment in children	• The impact of noise on cognitive impairment in children, such as delay in reading skills and oral comprehension, was identified as having sufficient evidence for marked negative impacts [22,26]
Fear	• RPA noise can create fear in members of the community who have a negative association with RPA • This can extend from privacy concerns, and fear of the unknown, to experience with RPA use in warfare [29]
Sleep disturbance	• Multiple papers have identified a link between aircraft noise exposure and sleep disturbance has been determined [22] • This included increased awakenings, decreased Slow Wave Sleep (SWS) time and non-prescribed sleep medication [27] • Movement and disturbance without awakenings had inconsistent results across studies [28]
Stress	• Constant, low frequency noise has been classified as a background stressor since the 1990s • It is noted that stress reduction is not possible for external noise and can result in stress symptoms and chronic psychophysiological damage [30]
Unpleasantness	• Low frequency noise has been determined to impact auditory perception, pressure on the eardrum, vibration of the chest, and general vibration • The impact on the ear results in the greatest feeling of unpleasantness [31,32]
Noise Induced Hearing Loss (NIHL).	• The categories of noise induced hearing loss include tinnitus, temporary hearing loss, or permanent hearing loss [33]

INFLUENCE ON COMMUNITY RESPONSE

Figure 10 and Table 7 show some of the recognised factors which influence response to noise. A key component of the noise response is the context of the situation, rather than generalised demographics [34].

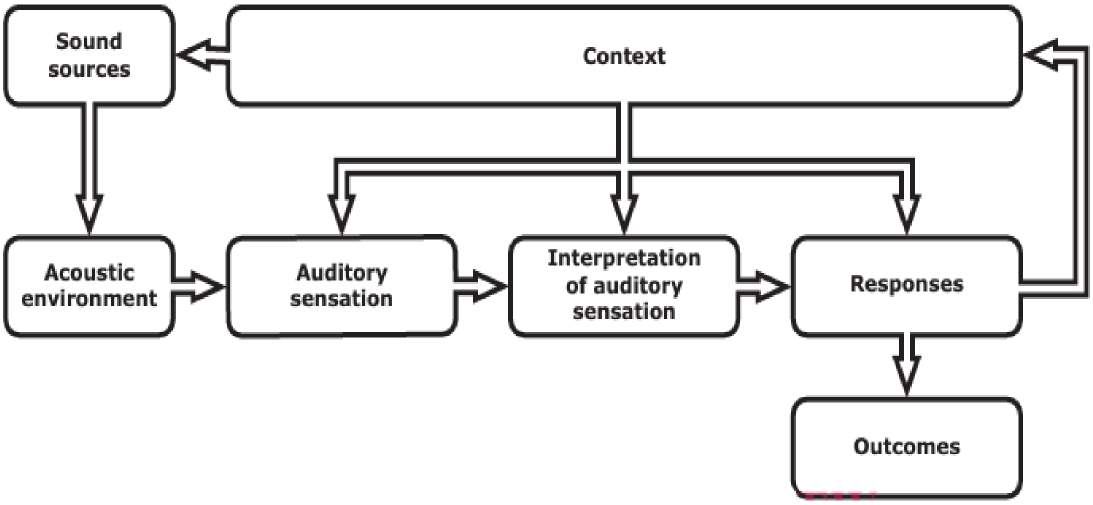

Figure 10 Elements in the perceptual construct of a soundscape [35]

Table 7 Influence on noise response

Influence	Description
Attitude	• Attitude towards the noise source influences how they perceive the sound [36]
Community engagement	• Community engagement, sufficient information and trust in authorities reduce annoyance ratings [22]
Control	• A sense of control over the noise or ability to cope (such as closing windows) reduces negative responses [16]
Demographics	• Demographics (age, gender etc.) were found to be unimportant for noise annoyance [22]
Fear	• Fear of the sound source or resulting actions of the sound source (such as fear of crash) influences the perception of aircraft noise
Non-noise	• Non-acoustic factors influence annoyance, such as the visual presence, or property intrusion [37]
Time of day	• Temporal factors (time of day and season) of the noise or the research can influence the response [22]
Utility of flight	• Perception of the purpose of the flight was found to influence the response • For example, participants who gained income from association with the noise were less annoyed [22], as were participants who were living near two airports [38]

NOISE MEASUREMENT

Noise measurement allows sound and the impacts of sound to be described and compared [1].

This section separates measurement into the categories of objective and subjective.

1. Objective noise measurements allow quantitative measurements of attributes and more easily allow for validity and reliability testing, showing repeatable data.
2. Subjective measurements explore attributes without necessarily having a consistent response across the sample. Validity and reliability in a qualitative context instead can refer to the research approach and consistency of the procedure, rather than the results.

Both approaches are required for understanding RPA noise, and both have issues in correctly measuring the attribute being investigated. This is in addition to the challenges of integrating the two measurement types.

OBJECTIVE MEASUREMENT OF NOISE

Objective measurement captures independent and external attributes. Figure 11 shows some aspects to consider when conducting objective measurement, with examples for each category. This section explores commonly measured metrics, issues and risks, and opportunities and best practice for this research approach.

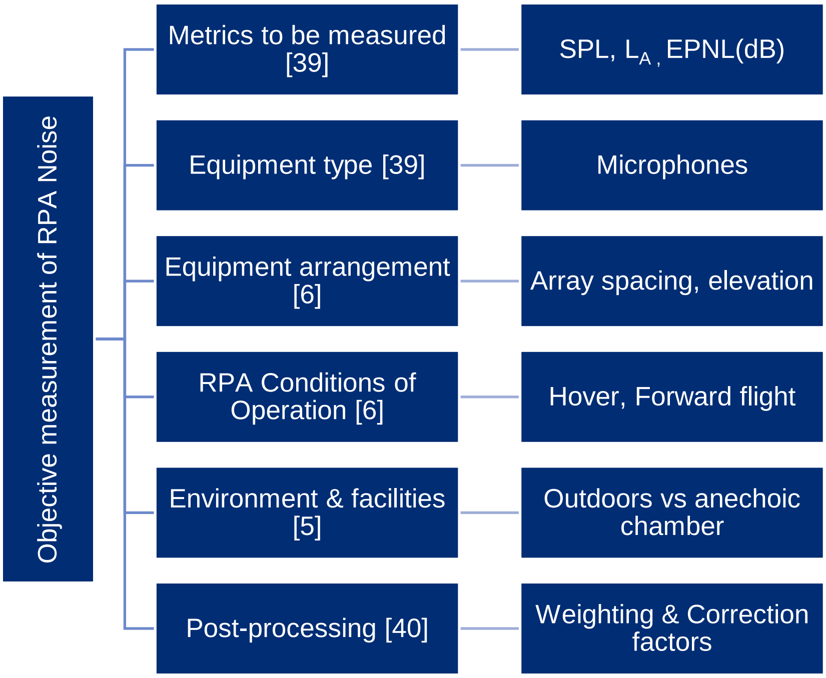

Figure 11 Objective measurement of noise diagram

METRICS TO BE MEASURED

Metrics in this context refer to units of measurement and other measurable attributes. These are shown in Table 8.

Table 8 Objective measurement metrics

<table>
<tr><th>Term</th><th>Description</th></tr>
<tr><td>Decibel dB</td><td>

A decibel is the unit used to measure sound (intensity, pressure, power, etc)
The decibel scale is logarithmic. Three of the most common metrics, all use the units ‘dB’. Due to the method for calculating or measuring each of these metrics, what constitutes a “doubling” of the metric’s value equates to an increase in decibels as shown in Table 9

Table 9 Decibel scale
<table>
<tr><td>Common metric</td><td>Doubling the value</td><td>Change in perceived sound</td></tr>
<tr><td>Power/Sound intensity</td><td>+3dB</td><td>Inaudible to barely perceptible change</td></tr>
<tr><td>Voltage/Sound pressure</td><td>+6dB</td><td>Noticeable increase</td></tr>
<tr><td>Loudness</td><td>+10dB</td><td>Twice as loud</td></tr>
</table>
</td></tr>
<tr><td>A-weighting, denoted as $L_{P}A$, measured in dB(A)</td><td>

The decibel level measured using an A-weighted filter is used to reflect the response by the human ear. 0dBA would be so quiet that the human ear would have problems detecting any noise [1,40]
This weighting cuts off very high, infrasound and low frequency noises that the human ear cannot hear
A large (e.g., 20dB) difference between the A and C weighting levels generally indicates that there is a high, low frequency or infrasound component to the noise [1]

</td></tr>
<tr><td>C-weighting, denoted as $L_{P}C$, measured in dB(C)</td><td>

The decibel level measured using a C-weighted filter is used to [1,40,41]:

Measure the highest and lower frequencies
Measure the maximum instantaneous sound level that the human ear is exposed to - peak sound level

</td></tr>
<tr><td>G-weighting, denoted as $L_{P}G$, measured in dB(G)</td><td>

Commonly used to measure infrasound and low frequency noise [1,40,41]

</td></tr>
<tr><td>Z-weighting, denoted as $L_{P}Z$, measured in dB(Z)</td><td>

A flat and specified frequency response between 10Hz and 20 kHz ± 1.5dB [1,40,41]

</td></tr>
<tr><td>dBA L_{eq}</td><td>

Unit of measurement to indicate average noise levels over a period of time [1,40,41]

</td></tr>
<tr><td>dBA L_{ex}</td><td>

Unit of measure for noise levels averaged over 8 hours [1,40,41]

</td></tr>
</table>

SUMMARY TABLES

The following tables (Table 10 and Table 11) show summarised findings from the literature. Identification of risks and issues from the literature have been combined to reflect the range of application contexts across the economies where issues may not yet be realised. Similarly, Opportunities and Best Practice have been collated, due to consideration of current operations but also because of overlap between a proven opportunity and what is determined as best practice. This approach is consistent throughout the report.

Table 10 Risk and issues for objective measurement

Common risks and issues	Description
Equipment	• Typically, Class 1 microphones are used for noise certification and research testing of aircraft • The cost of these microphones may be prohibitive for typical measurements of inexpensive small UAS, especially if a larger channel count is required to capture the directivity and variability of multirotor UAS noise [6] • This type of testing adds complexity for inexperienced entrants to the industry
Noise measurement	• Time averaged testing can result in the mischaracterization of sound patterns, particularly for transient, or changing broadband behaviour [6]
Vehicle scale	• Noise doesn’t scale in the same way aerodynamic performance properties might (for example, a drag coefficient measured at a representative Reynolds number for a scale model) • Advantage of experimental testing of RPAS platforms (compared to traditional crewed aviation) is the scale of the systems mean 1:1 scale testing (full-size) is often practical and not unreasonable [3]
Vehicle Operations	• The Doppler effect impacts noise measurement and capture due to the approach being different from recede levels [42] • There are operational instabilities in maintaining accurate hover [42] • Rotor and propeller noise is highly sensitive to changes in the aerodynamic operating condition, meaning no two flight passes will result in the same noise radiation pattern on the ground • This is an issue when measuring transient features but should average for static noise features with a sufficient sample size [42]
Environmental conditions can vastly impact perceived noise level	• Temperature and wind gradients can result in measured sound levels being very different to those predicted from geometrical spreading and atmospheric absorption considerations alone • These differences may be as great as 20dB [6,10]
Large variance in use cases and resultant noise	• The variance in use cases creates difficulty in standardising testing procedures and measurement metrics • Varied operational environments lead to changing end-result at the receiver (Figure 12)

Table 11 Opportunities and best practice for objective measurement

Common opportunities and best practice	Description
Positioning	New positioning methods for RPA have been created to capture more reliable location measurements [6].
Attributes	Attributes to be measured include: • All flight states to characterise noise over the entire operating envelope [6] • Time variance of rotor broadband noise and modulation to better understand psychoacoustic impacts [42] • Identified objective psychoacoustic metrics [40], such as roughness, harshness, sharpness, and fluctuation strength • Frequency and quantity of events in addition to event data [38]
Microphone positioning	Improvement for measurement includes [6]: • Offsetting the position of the microphone from the centre of a circular ground board or more complex “daisy petal” geometries to minimize edge diffraction effects • Larger ground boards maintain a flat frequency response across a wider range regardless of shape • The inverted microphone method is a close approximation to flush mounting over a frequency range determined by the spacing between the ground board and the microphone diaphragm • When time-varying noise measurements are to be conducted, both lateral and longitudinal angles must be measured simultaneously, therefore requiring a planar acoustic array

Figure 12 Proximity to community

SUBJECTIVE MEASUREMENT OF NOISE

Subjective measurement measures how noise is perceived and falls into the field of psychoacoustics. Figure 13 shows some aspects to consider when conducting subjective measurement, with examples for each category. This section explores commonly measured metrics, issues and risks, and opportunities and best practice for this research approach.

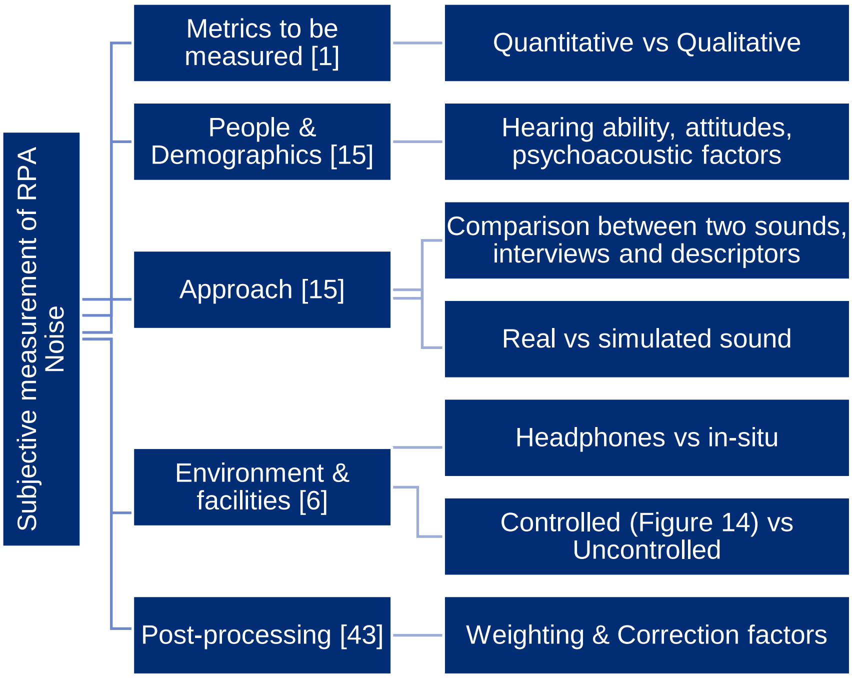

Figure 13 Subjective measurement diagram

Figure 14 Anechoic chamber testing

METRICS TO BE MEASURED

Metrics in this context, refer to units of measurement, and other measurable attributes. These are shown in Table 12.

Measurements can be taken for individual RPAs, environmental baseline noise, or to understand the cumulative impacts of multiple RPAs operating.

Table 12 Subjective measurement metrics

Term	Description
Lmax (dB(A))	• The single highest sampled level of sound and is used for night-time emission limits as a means of ensuring sleep protection • Short duration, high-level sounds such as audible warning devices, and pressure relief valves have a significant effect on Lmax values [40]
L10 or L10 (dB(A))	• The average maximum sound, calculated as the level of sound exceeded for no more than 10% of the monitoring period • The L10 unit was previously used in New Zealand as a good predictor of human annoyance at sounds in the environment [40]
L90 or L90 (dB(A))	• The background sound level, calculated as the level of sound exceeded for 90% of the monitoring period [40]
Leq,T or Leq,T (dB(A))	• The time-averaged sound level, referred to as an 'energy average' measure of sound exposure [40] • Considered the most suitable out of all acoustic data gathered (like peak level) to predict annoyance [44]
PHON	• A unit of the perceived loudness of sounds
SONE	• A unit to describe the comparative LOUDNESS between two (or more) sounds
Effective Perceived Noise Level (Epnl) - EPNdB	• PNdB plus a tone correction and a duration correction
Perceived Noise Level (Pnl) - PNdB	• Measurement of perceived noisiness to observers on the ground
Community Noise Equivalent Level (Cnel)	• The CNEL system gives a higher weighting to evening flights (1900 to 2200) and includes some correction factors based on: – Seasonal – Residential type – Previous community noise experience – Pure tone/impulse differences
Noise Exposure Forecast NEF	• A method, developed by the U.S. Federal Aviation Administration to predict the degree of community annoyance from aircraft noise (and airports) based on various acoustical and operational data

KEY RESEARCH APPROACHES

Some of the main types of methodologies used for the psychoacoustic evaluation of aircraft noise are shown in Figure 15.

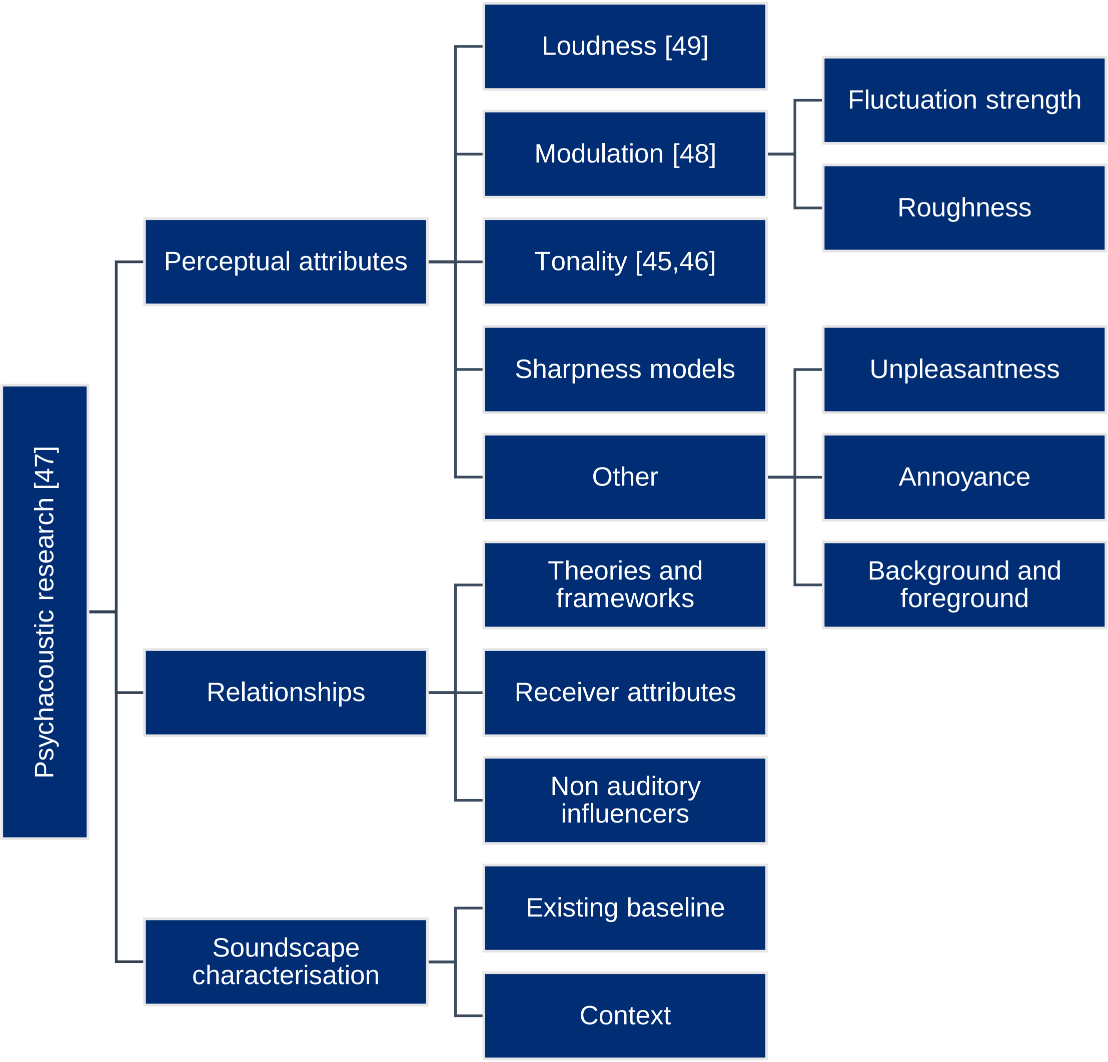

Figure 15 Key psychoacoustic research

SUMMARY TABLES

The following tables (Table 13 and Table 14) show summarised findings from the literature, exploring risks and issues, and opportunities and best practice.

Table 13 Risk and issues for subjective measurement

Common risks and issues	Description
Sound source	• Importance of quality of recording and speaker/earphones • Difficulty simulating sounds [6]
Test environment	• Difficulty calibrating environments both controlled and uncontrolled [6] • Putting someone in the chamber can lead to reactions and other attenuation [15]
Research method	• Using a reference sound makes everything referenced to that sound [15] • Using language descriptors can experience issues with certain descriptors [15] • Personal factors are constrained to those of the average person, meaning that only a limited number of subjects are protected by criteria that are developed from the assessment [50] • Difficulties exist in comparing community noise exposure response, due largely to the inconsistent metrics across the space: measurement techniques, questionnaires, data taken etc • Difficult to equate social surveys (how annoying is) which are subjective, with objective quantitative measurements, unless they can be done simultaneously, and instantaneously timestamped [51] • Many studies have different measurement methods or definitions for identifying the relationship with sleep disturbance • When sound is measured in longer timeframes, a sleep disturbance may be incorrectly attributed [28] • At high levels of low frequency noise (<100Hz), rating loudness and annoyance as equivalent begins to fail, meaning that measurements like dB(A) cannot predict annoyance [19]
Participant response	• Individuals were not always capable of differentiating between sounds well enough to make good use of a rating scale with fine resolution [15]

Table 14 Opportunities and best practice for subjective measurement

Common opportunities and best practice	Description
Calibrate field conditions	• Calibration can be achieved by checking for reactions with an impulsive test noise source, or by making measurements of spreading by the inverse square law [6]
Controlled test conditions	• Semi-reverberant acoustic field is a realistic alternative to anechoic [6] (Figure 14)
Furnished rooms for testing	• Similar calibration must be done to field testing, but it has the advantage of being easy to implement

NOISE MANAGEMENT AND MITIGATION

Management and mitigation work together to understand and improve an identified risk. Management is defined as the overall assessing and addressing of the issue, while mitigation is the reduction of something harmful or the reduction of its harmful effects. In this section, management and mitigation are categorised into governance and technical approaches to respond to RPA Noise.

Figure 16 shows how the categories have been organised for this section of the report and shows areas to apply management and mitigation approaches.

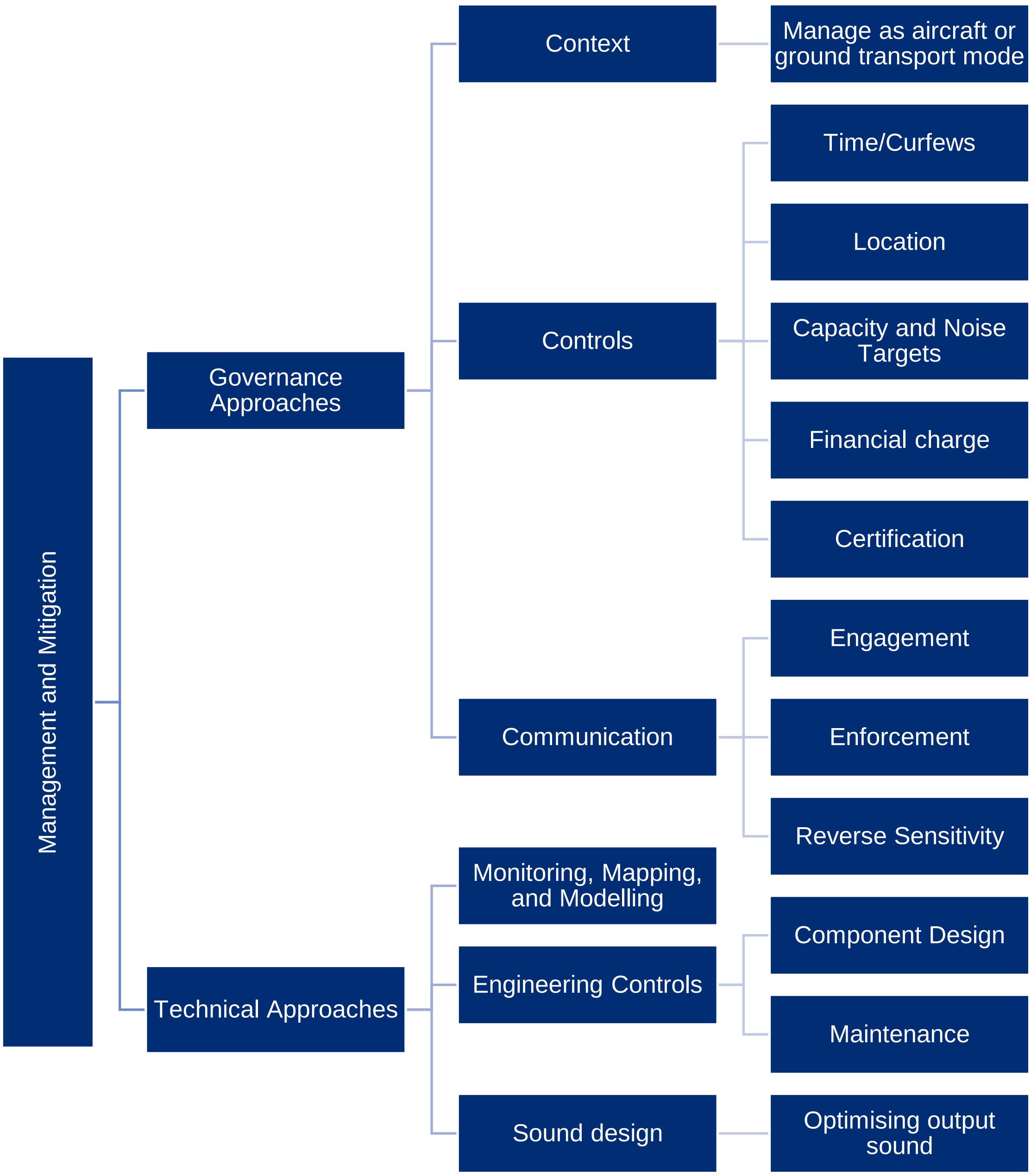

Figure 16 Management and mitigation diagram

GOVERNANCE APPROACHES

Governance approaches refer to areas that can be legislated or managed by a level of government. This includes:

- **Context:** how RPA noise is situated with other noise sources
- **Controls:** such as time and location restrictions, along with certification and targets
- **Communication:** includes enforcement, as well as engagement with existing residents in addition to new residents who might experience reverse sensitivity

It is acknowledged that these approaches will need to be created with consideration of local context, especially whereupon RPA noise exceeds the background noise by more than 5dB (the increase identified to cause annoyance [52]).

CONTROLS

Governance controls enable the governing body to influence operating behaviour. Controls for RPA noise have identified potential approaches in controlling:

- **Time:** provide guidelines around operational parameters that will reduce the time of sound impact and exposure, and therefore limit noise exposures
- **Location:** provide constraints and guidelines around flight paths and take-off and landing locations to reduce noise propagation into the community
- **Capacity and noise targets:** restrict the number of flights in an area or restrict the cumulative noise level in an area
- **Financial charge:** charge a noise levy for operators who exceed certain noise levels or for operating in an area
- **Certification:** require specific agreed and comparable RPA design standards

The following tables (Table 15 and Table 16) show summarised findings from the literature, exploring risks and issues, and opportunities and best practice.

Table 15 Risk and Issues for Controls

Common risks and issues	Description
Curfew	• Mandating and enforcing for all RPA users would be difficult
Flight path geometry	• Curved paths can potentially reduce noise propagation to people in a particular area, but brings the noise closer to others • Trajectory optimisation software is expensive, and resultant paths are hard to follow for pilots without guidance [6]
Capacity limits	• Mandating and enforcing for all RPA users would be difficult • ICAO suggests using capacity limits as a last resort [11]
Financial charge such as noise levy	• Prohibitive to remaining an accessible and inclusive industry
Certification validity	• Keeping a constant RPM is difficult for multi-rotors and this means that new acoustic testing procedures may need to be developed • Psychoacoustics are not fully considered in existing certification metrics, resulting in certified aircraft that can still annoy the community [6]
Noise limit	• It is noted that monitoring may show that current noise levels are considerably higher than established guidelines [53]

Table 16 Opportunities and best practice for controls

Opportunity and Best practice	Description
Flight path land type and use	Flight paths can result in lowest noise exposure to the community by: • Flying over undeveloped lands and waterways [54] • Following roadways to take advantage of the masking effect of traffic noise [54] • Maintaining high altitudes and high speeds [58]
General	• The WHO guidelines (2018) strongly recommend avoiding exposure to more than 45dB Lden, as *"this level is associated with adverse health effects"* [26]
Night-time	• The WHO guidelines (2018) strongly recommend limiting night-time exposure to less than 40dB Lnight, as *"this level is associated with adverse effects on sleep"* [26]
Indoor	• Indoor sound level guideline values set by WHO for bedrooms are 30dBA Leq for continuous noise and 45dBA Lmax for single sound events. [26,40]

COMMUNICATION

Communication enables the community to be aware of relevant information and engage with levels of government to share their opinion. Communication from the governing body can appear as:

- **Community Engagement:** Communicating and working with the local community to reach mutual objectives, including awareness of RPA noise requirements and feedback mechanisms
- **Enforcement:** Ensuring compliance with the requirements is occurring
- **Reverse Sensitivity:** Managing the expectations of new residents in an area with typically higher noise levels

The following tables (Table 17 and Table 18) show summarised findings from the literature, exploring risks and issues, and opportunities and best practice.

Table 17 Risk and issues for communication

Common risks and issues	Description
Reverse sensitivity	• Difficulties often arise where noise-sensitive land uses (such as residential activities) move into, or close to, established commercial areas or major infrastructural assets such as ports or airports [40]
Communication	• Community feels unheard • New control measures are not understood or known
Enforcement	• Insufficient resources to manage enforcement activities • Lack of enforcement leads to controls not being followed

Table 18 Opportunities and best practice for communication

Opportunity and Best practice	Description
Reverse sensitivity	• One technique for dealing with the issue of reverse sensitivity is to ensure people are fully informed of the existing effects of the environment which they are proposing to move into [40]
Communication	• Continuous community engagement processes from the inception of designing governance approaches
Enforcement	• Income based fines

TECHNICAL APPROACHES

Technical approaches refer to areas that can be managed or mitigated through technical practices. This includes:

- **Monitoring, mapping, and modelling:** Simulating and tracking noise conditions
- **Engineering controls**: Modifying designs
- **Sound design:** Optimising output sound

MONITORING, MAPPING, AND MODELLING

Monitoring, mapping, and modelling enable oversight of existing and future levels of RPA noise in an environment through simulated prediction or measurement practices. This enables decisions to be made based on current conditions, and the estimated capacity of the environment.

An example of this, is the Australian Noise Exposure Forecast (ANEF), shown in Figure 17, a system that is based on a modified version of the FAA Noise Exposure Forecast. The approach determines forecasted noise contours around an airport to depict exposure areas. Flight schedules, paths, and aircraft types are factored into the forecasted contours.

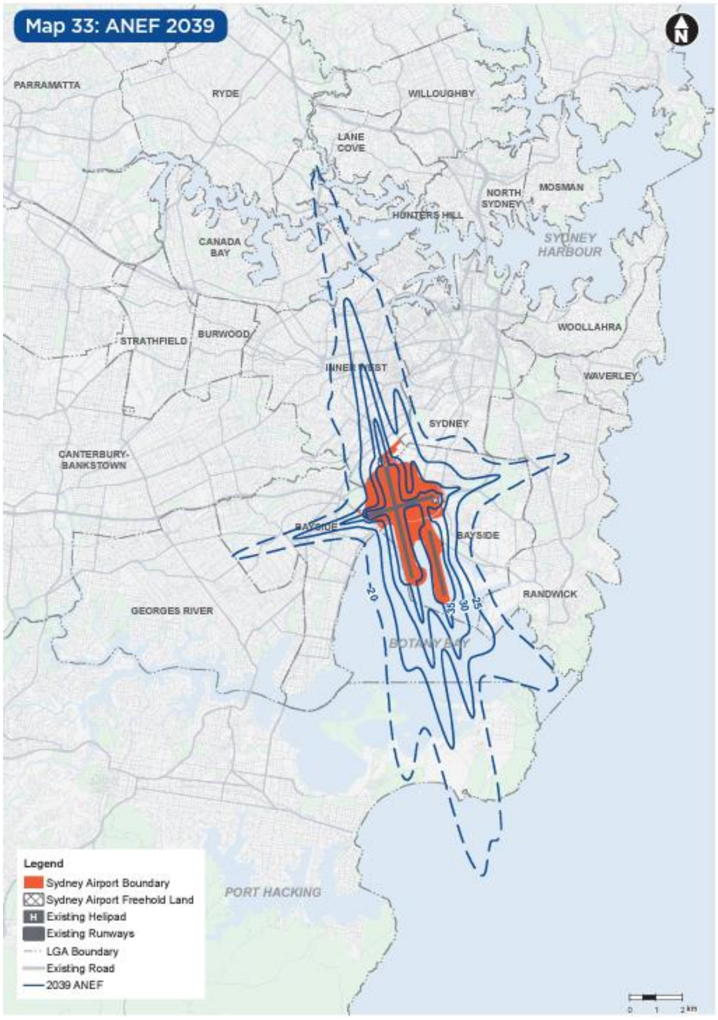

Figure 17 Sydney ANEF 2039 map [63]

The following tables (Table 19 and Table 20) show summarised findings from the literature, exploring risks and issues, and opportunities and best practice.

Table 19 Risks and issues of monitoring, mapping, and modelling

<table>
<tr><th>Common risks and issues</th><th>Description</th></tr>
<tr><td>Modelling sound</td><td>

• Difficulty of modelling all aspects – some are shown in Figure 18

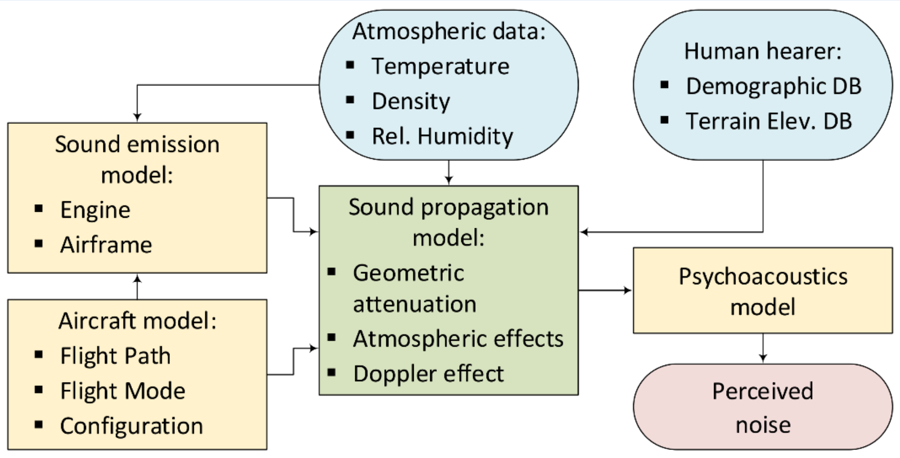

Figure 18 Modelling flowchart [9]

• Subjective perception [55]
• Directivity effect between horizontal and vertical radiation direction [56]
</td></tr>
<tr><td>Modelling RPA operating behaviour</td><td>• Difficulty in modelling noise levels from all noise sources and interactions [6]
• No steady state assumption, meaning RPA noise cannot be modelled as a single stationary source [6]
• Difficulty with wake prediction for eVTOL due to the long wake ages associated with many interactions [6]
• High cost of modelling limits more accurate outputs [6]</td></tr>
</table>

Table 20 Opportunities and best practice for monitoring, mapping, and modelling

Opportunity and Best practice	Description
Sound library	• Create shared sound libraries of RPA recordings [54] • Synthesise and modify RPA recordings to investigate acceptable noise range [55]
Modelling capabilities	• CFD has advanced to model turbulence, grid generation, and high-order schemes for full vehicle simulations [6] • A new module has been developed for PSU-WOPWOP which enables arbitrary Finite Impulse Response (FIR) filters to be applied to measured or predicted signals [57]
Modelling assumptions	• Thickness noise of a variable RPM rotor can be considered “quasi-steady” [6] • Sources can be treated as nondeterministic or incoherent [6]

COMPONENT DESIGN

The ICAO guidance for a balanced approach [60], supports the reduction of noise at the source. This can be achieved by optimising component design through passive and/or active noise control methods. These advances in design can be integrated into design recommendations or used to show where noise reductions can be made.

The following tables (Table 21 and Table 22) show summarised findings from the literature, exploring risks and issues, and opportunities and best practice.

Table 21 Risk and issues for component design

Common risks and issues	Description
Propeller	• Propeller designs optimised for low noise often have trade-offs with other properties (e.g., efficiency) [7]
Cost and access	• Optimised components, as well as Research and Development, can impact entrants to the industry who can only access off the shelf existing products

Table 22 Opportunities and best practice for component design

Common opportunities and best practice	Description
Propeller	Methods to reduce noise include: • Increasing propeller number and reducing rpm [59] • Surface modifications, such as serrations and porosity [6]
Airframe	Methods to reduce noise include: • Porous edges [7] • Sawtooth edges [7] • Serrated trailing-edge corners [7] • Small vortex generators referred to as ‘microtabs’ [7] • Active control techniques can consist of continuously blowing air into the vortical structure to counteract the vortex roll-up, and to displace the vortical structure away from the solid surface [7]
Maintenance	Methods to reduce noise include: • Airframe and engine gas-path ‘cleanliness’ [60] • Minimising and managing weight [60] • Reducing and removing acceptable defects (adds) affecting noise performance [60] • Incorporation of any product improvement and software packages that may help improve the aircraft’s noise performance [60]
Engine/motor	Methods to reduce noise include: • High torque electric motors

SOUND DESIGN

Applying lessons learnt from the field of psychoacoustics to sound design can enable the creation of a desirable soundscape. Sometimes created solely to meet sound targets, ideally, a soundscape embodies the characteristics required to elicit a positive response within the relevant context (e.g., a design suitable for an outdoor performance space is unlikely to be considered equally suitable for a library). The variation in opinion regarding the soundscape, even within a community, combined with contextual factors makes effective sound design quite challenging. Unfamiliar noises were commonly found disturbing but there was some desire for acoustic action feedback [61].

The following tables (Table 23 and Table 24) show summarised findings from the literature, exploring risks and issues, and opportunities and best practice.

Table 23 Risk and issues for sound design

Common risks and issues	Description
Attitude towards flight types	• A common comment from subjects was that sounds that appeared to 'loiter' were judged more harshly [62] • An example would be deliveries to multiple properties in a small neighbourhood (Figure 19)
Increased noise sensitivity	• People can become annoyed at lower sound levels [23,38]

Table 24 Opportunities and best practice for sound design

Common opportunities and best practice	Description
Sound design	• Noises that rise in intensity too rapidly cause the startle response • A time-based correction is possible to reduce this [62]
Masking	• Masking RPA noise as part of another noise could help reduce the human response to noise [6]

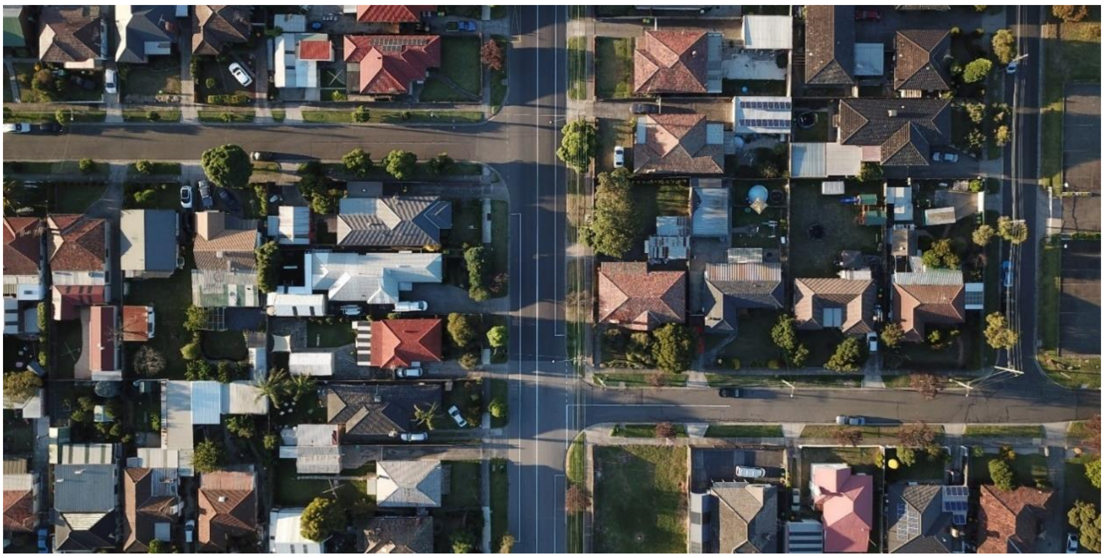

Figure 19 Community layout influences sound design

CURRENT RPA NOISE MANAGEMENT WORK

Table 25 provides an overview of some of the major undertakings concerning the understanding, management, and regulation of RPA noise. It includes examples of work from the academic or research and development (R&D) space, international working groups determining policy and best practice, and covers the modelling, measurements, and impact of RPA noise. Additionally, it is known that there is work being done in the commercial space where “quiet” or “low noise” iterations of a product are created. Due to the limited publicly available information regarding these development activities, they have been excluded.

The listed projects provide a cursory overview of programs and activities, and further consultation with APEC economies elicited initial work being conducted by the following economies:

- Canada
  - Initial research
- China
  - RPA noise committees
- New Zealand
  - Enabling Drone Integration 2021
    - Consultation on a package of measures called Enabling Drone Integration
    - Noise issues were included in some submissions
- The Philippines
  - Development and compliance with local airport noise management[5]
- Russia
  - Creation of documents that are not publicly available
  - Most of the documents are under consideration by the state authorities or other stakeholders
- Chinese Taipei
  - Initial research into:
    - Noise level
    - Noise measurement method, except for FAA part 36.

Table 25 Identified current RPA noise work

Project	Organisation	Description
Draft ISO standard	ISO (International Organization for Standardization)	ISO/CD 5305 General requirement of noise measurement of lightweight and small multirotor unmanned aircraft systems (UAS)
Ascent	FAA AEE	Projects are being run through several universities: • A38 Rotorcraft Noise Abatement Procedures Development • A49 Modeling of Urban Air Mobility Noise to Enable Innovative Means of Noise Reduction • A61 Noise Certification Streamlining

[5] https://caap.gov.ph/rpas

		• A077 Measurements to Support Noise Certification for UAS/UAM Vehicles and Identify Noise Reduction Opportunities • A84 – AEDT/ANOPP2 Modeling of AAM Vehicle Operations • A94 – Probabilistic Unmanned Aircraft Systems (UAS) Trajectory and Noise Estimation Tool
UAM Noise Working Group	NASA	NASA has formed a working group to define and address UAM-related noise issues. Made up of a broad range of stakeholders, the Urban Air Mobility Noise Working Group addresses UAM issues in four high-level areas: • Tools and technologies, • Ground and flight testing • Human response and metrics • Regulation and policy
NASA National Campaign	NASA	A series of flight demonstrations over the next several years will collect acoustic measurements.
Annual Symposium	Quiet Drones	The Symposium provides a venue for researchers on drone noise to meet with manufacturers, users and those engaged in designing innovative applications for this new technology.
The Committee on Aviation Environmental Protection (CAEP)	ICAO	CAEP assists the Council in formulating new policies and adopting new Standards and Recommended Practices (SARPs) related to aircraft noise and emissions, and more generally to aviation environmental impact. The WG1 work programme for the CAEP/12 cycle (2019-2022) includes various topics such as *“Research monitoring and new entrant noise”.*
Public consultation on RPA noise regulations	Australia	Public consultation on the proposed amendments to the Air Navigation (Aircraft Noise) Regulations 2018 to incorporate RPA use. Submissions can be viewed at https://www.infrastructure.gov.au/infrastructure-transport-vehicles/aviation/emerging-aviation-technologies/managing-drone-noise/noise-regulation-review-remotely-piloted-aircraft-rpa-and-specialised-aircraft”.

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COMPARISON OF ECONOMY REGULATIONS

Each APEC economy has their own regulatory and policy parameters relevant to RPA noise, with some economies also having targeted RPA noise regulations.

The governance approaches for each APEC economy have been identified and compared and are shown in Table 26 and Table 27 with the legend in Figure 20 explaining the symbols. This information has been obtained solely from open source, accessible, online information to replicate the experience of someone looking for this information.

Table 26 Comparison of RPA directly related economy regulation

	RPA-specific noise regulations or policy	RPA Noise Complaints process (RPA Specific)	Regulatory Distinction between Hobby and Commercial RPA Operations	RPA Registration requirements (hobby)	RPA Registration requirements (commercial)
Australia	✓ (orange)	✓	✓	✓	✓
Brunei Darussalam			✓	✓	✓
Canada				✓	✓
Chile			✓	✓	✓
People's Republic of China			✓	✓	✓
Hong Kong, China					✓
Indonesia			✓		✓
Japan			✓		✓
Republic of Korea			✓	✓	✓
Malaysia			✓		✓
Mexico			✓	✓	✓
New Zealand					
Papua New Guinea					
Peru			✓	✓	✓
The Philippines			✓		✓
Russia			✓		
Singapore			✓	✓	✓
Chinese Taipei			✓	✓	✓
Thailand			✓	✓ (orange)	✓ (orange)
United States			✓	✓	✓
Viet Nam				✓	✓

Information available

Additional Information:

Australia – RPA Noise is specifically included in the Air Navigation (Aircraft Noise) Regulations 2018 (Cth). Any RPA over 250 grams operated outside of the Standard Operating Conditions needs approval from the Department of Infrastructure[6].

Thailand – An RPA with camera or recording equipment and over 2 kilograms must be registered.

Figure 20 Legend for regulation comparison

Table 26 shows most APEC economies differentiate between hobby and commercial RPA operators and that registration is typically required, with more economies requiring it for commercial operations. Australia was the only economy to have a specific complaint process for RPA noise.

Table 27 shows that six of the 21 economies have current or future RPA noise work being undertaken, and that the majority have training or preparation requirements before the registration or licencing process. Community engagement prior to changes occurring was not shown to be consistent across economies, and nine of the economies did not have an obvious complaints approach for general noise.

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Table 27 Comparison of RPA indirectly related economy regulation

	Noise Regulations/policy (not RPA specific)	Noise Complaints Process (generic)	RPA specific Education and training /licence preparation courses	Community engagement prior to upcoming changes in the community (project related)	Noise Research / Ongoing Development (RPA specific) Future Projects
Australia	✓	✓	✓	✓	✓
Brunei Darussalam	✓		✓	✓	✓
Canada	✓	✓	✓	✓	✓
Chile	✓	✓			
People's Republic of China	✓	✓			
Hong Kong, China	✓	✓	✓	✓	✓
Indonesia	✓	✓	✓	✓	
Japan	✓		✓		
Republic of Korea	✓		✓		
Malaysia	✓	✓	✓		
Mexico	✓		✓		
New Zealand	✓	✓	✓	✓	✓
Papua New Guinea	✓	✓	✓		
Peru	✓		✓		
The Philippines	✓	✓	✓		
Russia	✓		✓		
Singapore	✓	✓	✓		
Chinese Taipei	✓		✓		
Thailand	✓		✓		
United States	✓	✓	✓	✓	✓
Viet Nam	✓				

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STAKEHOLDER ENGAGEMENT AND CONSULTATION

SUMMARY OF SURVEY FINDINGS

A survey protocol was developed to capture views of the APEC economies and enable sharing of existing knowledge and related work.

SURVEY DESIGN

The survey comprised two sections: RPA questions, and demographic questions.

To capture the desired information without overburdening the respondents and possibly resulting in incomplete responses, a balance of questions and topics was created.

The survey protocol included the following questions which have been categorised for analysis purposes:

- RPA Usage
  - Estimated number of RPA being used in your economy, per RPA use case
- RPA Pilot Behaviour
  - In general, how do you rate the behaviour of RPA operators in your economy?
  - Do you think it is likely that RPA operators in your economy will follow noise regulations?
  - If your economy already has RPA noise regulations, how likely do you think it is that RPA operators currently abide by them?
- Existing Management and Mitigation Strategies
  - Which of the following methods are in use by your economy to manage or mitigate RPA noise?
  - What noise (other than RPA noise) regulations, guidelines, or restrictions already apply to outdoor environments in your economy?
- Existing RPA Noise Knowledge
  - What challenges, risks, or hazards has your economy identified concerning RPA noise?
  - What opportunities or best practice has your economy identified concerning RPA noise?

The demographic questions collected information about the respondents, enabling gender and economy participation statistics, and comparative analysis to be conducted on full or partial data sets.

DISTRIBUTION

CO-SPONSORING ECONOMY SURVEY

The first iteration of the survey was distributed to the participant list provided by the Project Overseer (PO) (Australia), which included the co-sponsoring economy contacts, excluding Australia. The survey was conducted using Microsoft Forms, based on an assessment of accessibility for all member economies.

Seven responses were received from the co-sponsoring economies: Canada; New Zealand; The Philippines; Singapore; Chinese Taipei and two separate responses from the United States. No responses were received from Japan or Thailand.

Of the seven respondents, one was female, and six were male. This might have been influenced by the distribution list not having equal gender diversity (assumed based on numbers of gendered western names or noted prefixes (e.g., Mr)).

When considering the participation ratio of women in this project, it is noted that the PO and supporting team are female, as well as the two primary consultants.

ALL-ECONOMIES SURVEY WITH WORKSHOP REGISTRATION

To collect a broader range of responses, a second iteration of the survey was distributed to all member economies, with the ability for economies to share with non-member stakeholders.

This survey was modified to include the stakeholder workshop registration link and was conducted using Google Forms, following the APEC Secretariat request. The questions, wording and format from the initial survey were retained to ensure a consistent approach across the two survey distributions.

Responses were received from 10 economies: Australia; Canada; China; Indonesia; Malaysia; Mongolia (non-member); New Zealand; the Philippines; Russia; and Singapore.

Of the 27 respondents, eight identified as female, and 19 identified as male. This achieved a 30% female participation rate, doubling the first survey iteration rate of 14%.

To increase gender diversity and encourage female participation throughout the remainder of the project, a gendered working group session was designed.

SURVEY RESULTS

The two survey distribution results were combined to enable an analysis of the entire data set.

PARTICIPATION

34 responses were received across the two survey distributions.

12 economies were represented in the survey data, as shown in Figure 21. 11 were member economies, and one was a non-member economy.

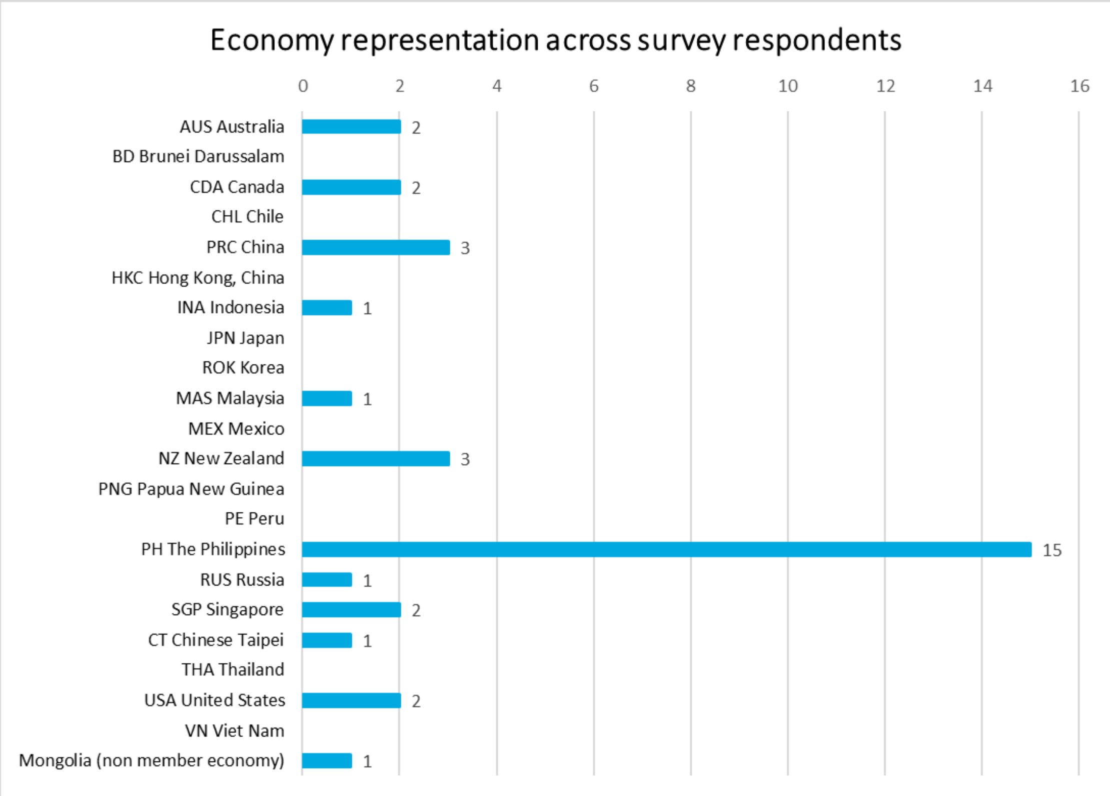

Figure 21 Economy survey participation

Participant gender[7] was self-identified as nine women, and 25 men, as shown in Figure 22. This resulted in a 26% female participation rate across the two surveys.

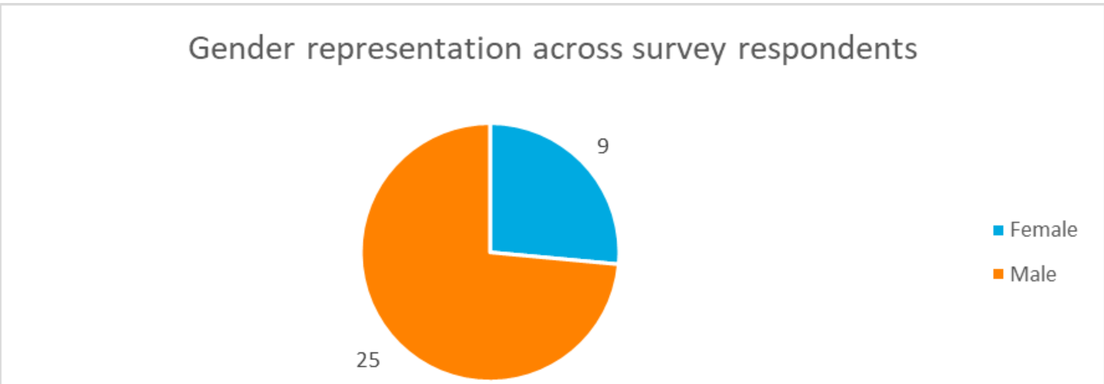

Figure 22 Survey participation by gender

[7] APEC Guide for Gender Analysis categorises gender into the binary of men and women.

EXISTING MANAGEMENT AND MITIGATION STRATEGIES

Management and mitigation strategies were explored to understand approaches towards RPA noise and noise more broadly.

To understand current approaches to RPA noise, respondents were asked to select from a provided list of management and mitigation techniques or provide a text response by selecting “other”.

Figure 23 shows the distribution of responses for the various management and mitigation approaches. The categories show the approaches provided to survey respondent and the numerical scale shows the number of respondents who selected that approach.

Complaints and feedback process, general noise regulations, specific RPA regulations, and none, each represented over 10% of the responses.

The responses that fell into the “other” category were:

- “Resource management regulations at local government level”
- “Complex regulation (from general noise regulations to special cases)”

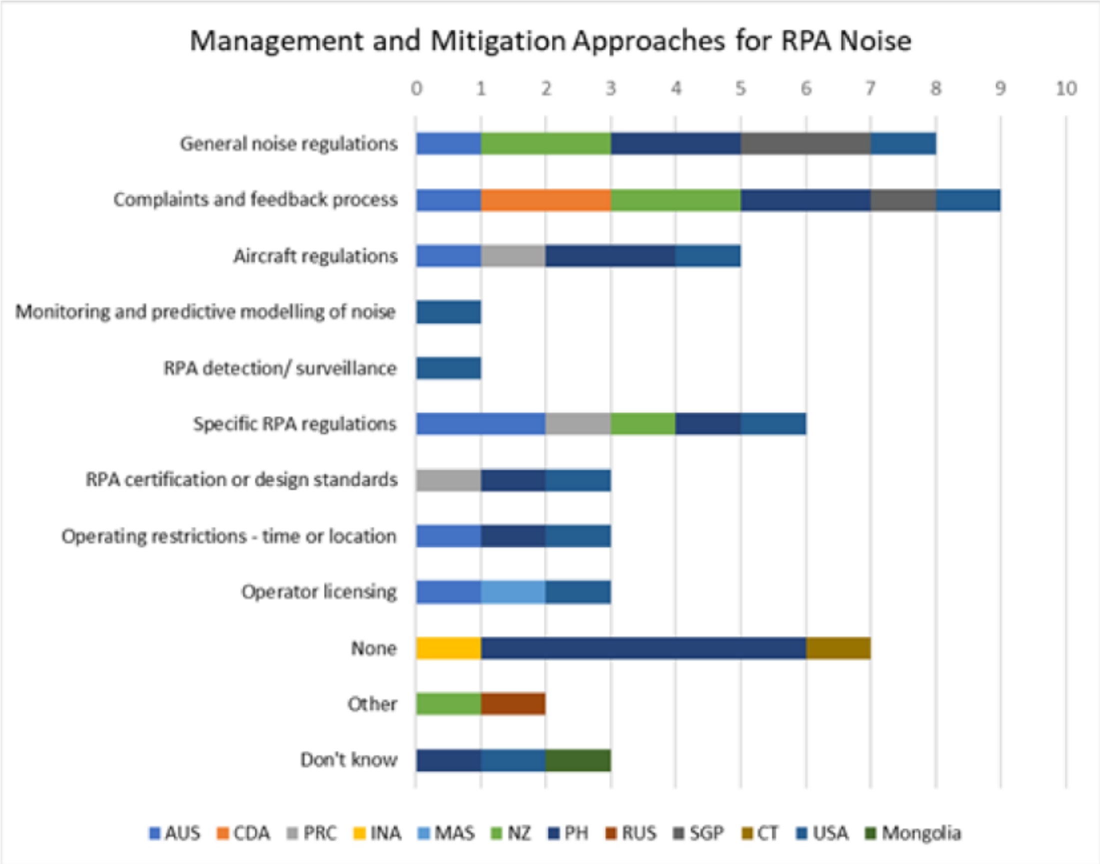

Figure 23 Current RPA noise management and mitigation

To understand how noise generally is managed, participants were asked about regulations, guidelines or restrictions that currently apply to outdoor environments. This allowed insight into the various ways noise can be managed depending on context and how it integrates into overarching regulations – a key consideration for RPA which function across sectors.

Figure 24 categorises the responses received to show the range of approaches from respondents.

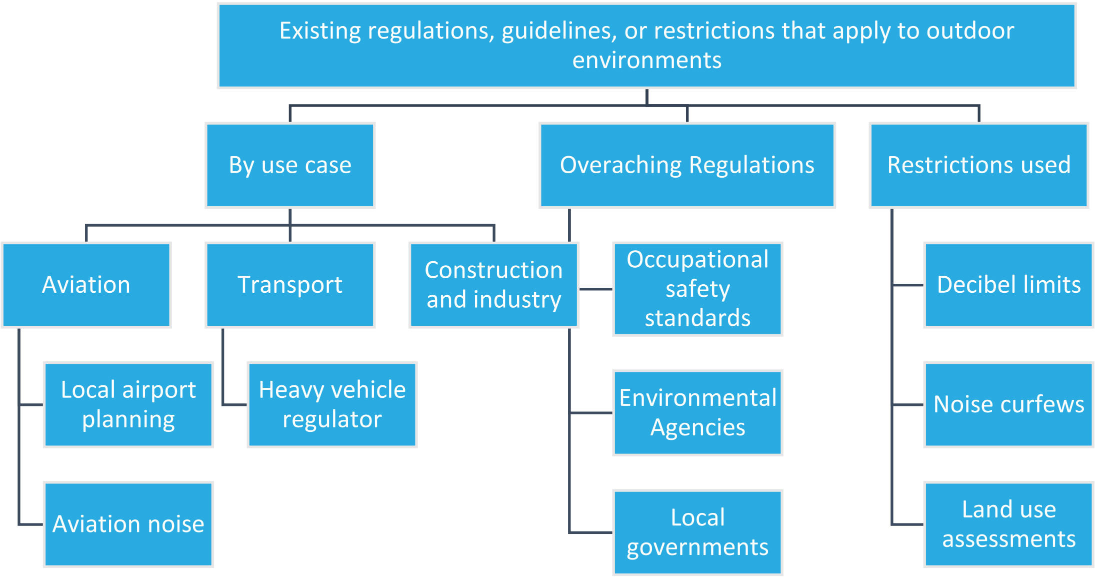

Figure 24 Outdoor noise management

EXISTING RPA NOISE KNOWLEDGE

Respondents were asked to provide insight into known challenges and risks, identified opportunities, and relevant work conducted in their economy to enable understanding of the existing RPA knowledge baseline, and share any learnings.

As shown in Figure 25, “Don’t know” and “None” comprised a large percentage of the responses to each of the questions in this category. These responses have been excluded from the following result summaries in this section to enable focus on the other responses.

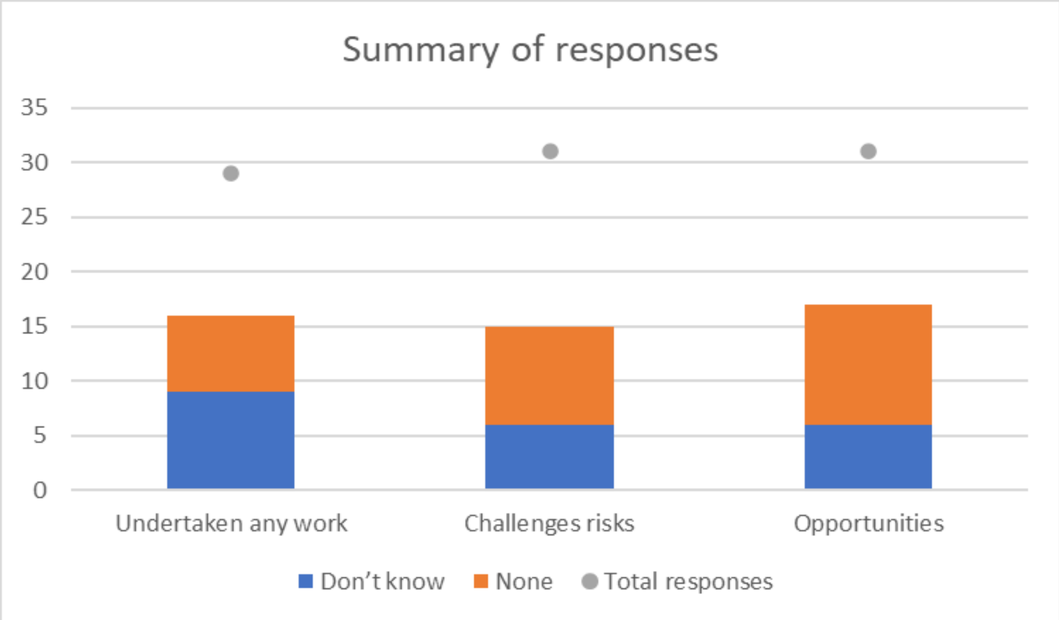

Figure 25 RPA noise knowledge summary of response types

Respondents were asked to provide detail about RPA noise work undertaken in their economy. Figure 26 shows the proportion of work mentioned in survey responses and Figure 26 details relevant responses per economy as direct quotes.

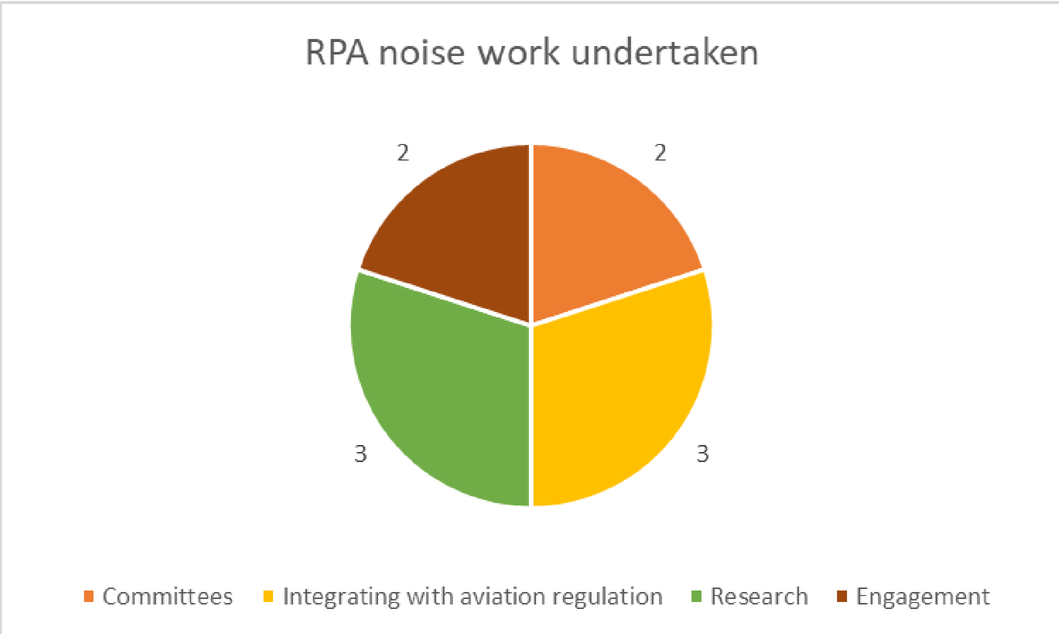

Figure 26 RPA noise work undertaken

Table 28 RPA noise work undertaken

Economy	Relevant work undertaken
Australia	*“Public consultation on the proposed amendments to the Air Navigation (Aircraft Noise) Regulations 2018 to incorporate RPA use - see submissions at https://www.infrastructure.gov.au/infrastructure-transport-vehicles/aviation/emerging-aviation-technologies/managing-drone-noise/noise-regulation-review-remotely-piloted-aircraft-rpa-and-specialised-aircraft”*
Canada	*“Not yet, just some research started”*
China	*“Yes, currently as committees”*
New Zealand	*“Not specifically. In 2021 we consulted on a package of measures called Enabling Drone Integration. While not a focus of the proposals, some submitters did mention noise issues in their feedback. RPA noise is generally considered alongside other social licence issues such as privacy, visual pollution, and environmental impact, etc.”*
The Philippines	*“Development and compliance to local airport noise management https://caap.gov.ph/rpas/”*
Russia	*“Yes, but the documents are not publicly available (most of the documents are under consideration by the state authorities or other stakeholders)”*
Chinese Taipei	*“We are researching the noise level as well as the measurement method except for FAA Part 36.”*

Participants were asked to identify challenges, risks, or hazards concerning RPA noise, to understand commonalities and differences across the economies. The responses have been categorised into six key challenge areas and are quoted below in Table 29.

Table 29 Challenges, risks, and hazards

Theme	Survey quote or observation
No challenge or risk perceived or known	*"To date we have had little to no challenges regarding RPA noise. We expect that proliferation of RPA (probably) creating noise where previously there was none/little previously will need to be addressed in the future. This is likely to be done is a holistic way alongside other emerging technology initiative."* *"Generally, drones are being operated in the daytime where the noise level are more acceptable. So there is not much of an issue for now."* • Nine other responses stated their economy have not identified any challenges, risks, or hazards • Six responses stated "don't know" or "not aware"
Social licence	*"RPA Noise poses a risk to community's 'social licence' for drones to operate. A big risk is from nuisance recreational drone use as recreational drone noise is not captured under Australia's RPA Noise Regulations and no action can be taken unless the drone operator is breaching safety rules."* *"Most commercial operators seem to understand that social licence is fragile and take steps to minimise their noise impacts."* *"It should be related to public acceptance and needed to address the concerns to the RPAS community for their attention."*
Interaction	*"Interference with normal life."* *"Distraction to populous area"* *"Our airport is located within the immediate vicinity of a residential housing"* *"Public disturbance"* *"RPA will be operated in lower airspace than regular aircraft. The number of operations can be many with the improvement of technologies. Annoyance level would be high."*
Psychoacoustics	*"It is subjective and difficult to define. A concern for one person, may not be for another."*
Safety	*"Hearing safety, community health (mental)"* *"Surveillance"* *"Script logic errors, Task formulation errors, Infrastructure failure, Security"*
Measurement	*"Need noise measuring and analyzing tools"*

The final RPA noise question for participants was to share any opportunities or best practice identified by their economy.

Six respondents stated that they were unaware of any opportunities, and a further eleven stated that there were none known by their economy. The remaining responses were analysed into four categories: governance, engagement, technical approaches, and measurement, with respondent quotes shown in Table 30.

Table 30 RPA noise opportunities or best practice

Themes	RPA noise opportunities or best practice
Governance	*"Regulations to industry and operators"* *"Performing a schedule of flights with respect to the type of aircraft (or noise it produces) so as not to affect the quality of life of the general public in the immediate vicinity."* *"Noise level labelling"* *"CORSIA"* • A harmonized way to reduce emissions from international aviation, minimizing market distortion, while respecting the special circumstances and respective capabilities of ICAO Member States *"MCAR"* • Malaysian Civil Aviation Regulations
Engagement	*"The Civil Aviation Authority has regular engagement with particular communities experiencing noise issues, as well as local councils, to help resolve issues and ensure that relevant parties are talking to one another. This applies to all forms of aviation, not just RPA, but the principle still applies that they seek to utilise 'non-regulatory' or 'soft' tools as we think they're often a better approach. Most noise abatement considerations happen at local government level. This is because they are generally responsible for determining land use under Resource Management Act and are better placed to a) balance the competing interests of the people living in their communities and b) apply any noise measurement methods or standards."* *"We are working with mostly commercial package deliveries at this point using the same noise regulations for regular aircraft."* *"We encourage drone operators to act responsibly."*
Technical Approaches	*"Multidisciplinary optimization design of propeller."*
Measurement	*"Live community trials for larger scale commercial operations are important. Wing's Bonython (ACT) trial showed that the pitch, rather than the decibels, was a critical factor in many noise complaints. They redesigned their drones to lower the pitch and it is these newer models they now use for their operations in Logan (Queensland) and Mitchell (ACT)"* *"So far, we will require the POC (proof of concept) drone delivery project to assess the noise data during their experimental activities to build up the experience data for future regulating needs."*

SUMMARIES OF ONLINE STAKEHOLDER CONSULTATION MEETINGS

Five online stakeholder meetings, or working groups, were developed to investigate key themes identified through the desktop research and survey analysis. The identified themes for the targeted discussions were governance, technical approaches, measurement, and community impact.

A fifth stakeholder meeting was created for female identifying participants. This was designed to support balanced participation across the genders, enable discussion of the impact on less privileged groups in a potentially safer environment, and understand the gendered impact of RPA noise.

Each stakeholder meeting included:

- An introduction
- Request for voluntary demographic information
- An opening question about the problem and accountability
- A brief overview of relevant information
- Key questions to explore using a collaborative whiteboard (example in Figure 27)

The stakeholder meetings are summarised in the sections below, including key quotes from participants.

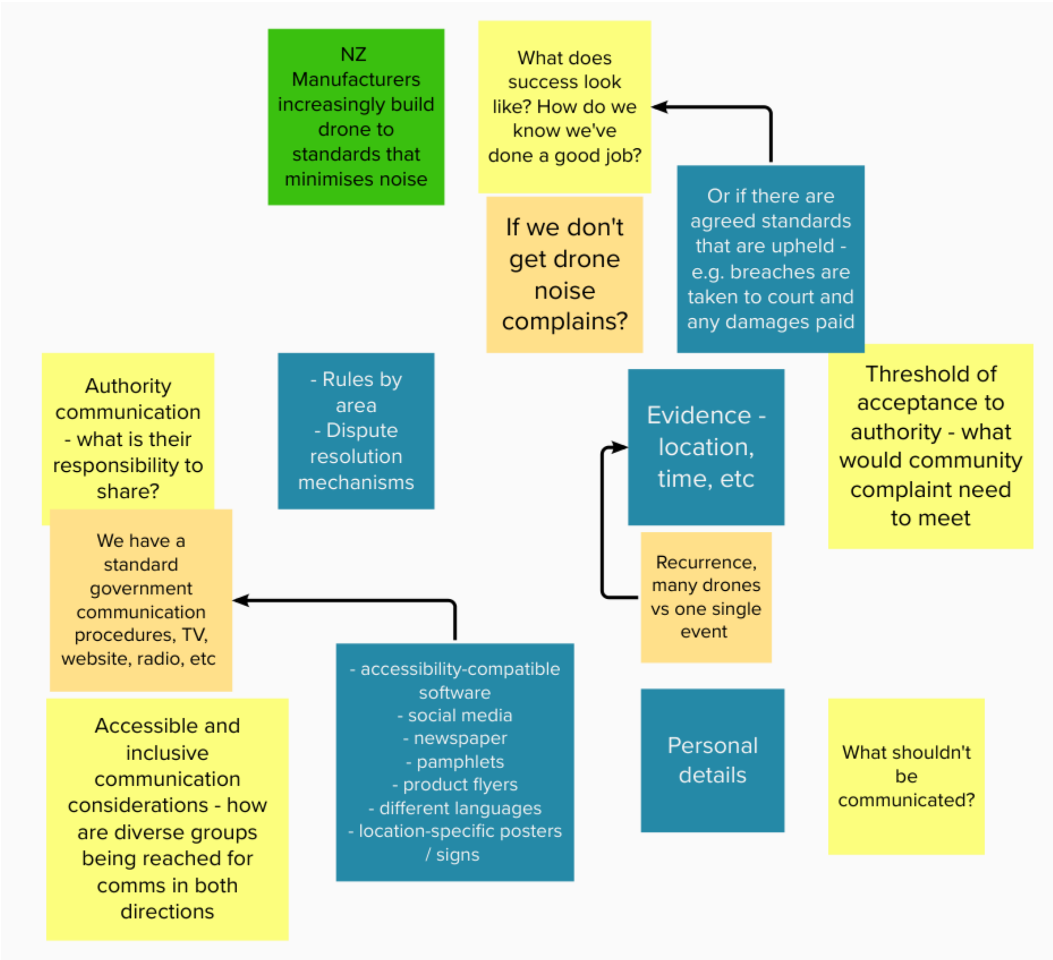

Figure 27 Collaborative whiteboard

PARTICIPATION

Figure 28 and Figure 29 show the participation separated by gender and economy to demonstrate the representation achieved within the stakeholder consultations.

The Project Overseer and their colleagues have been included as participants in the participant summary figures.

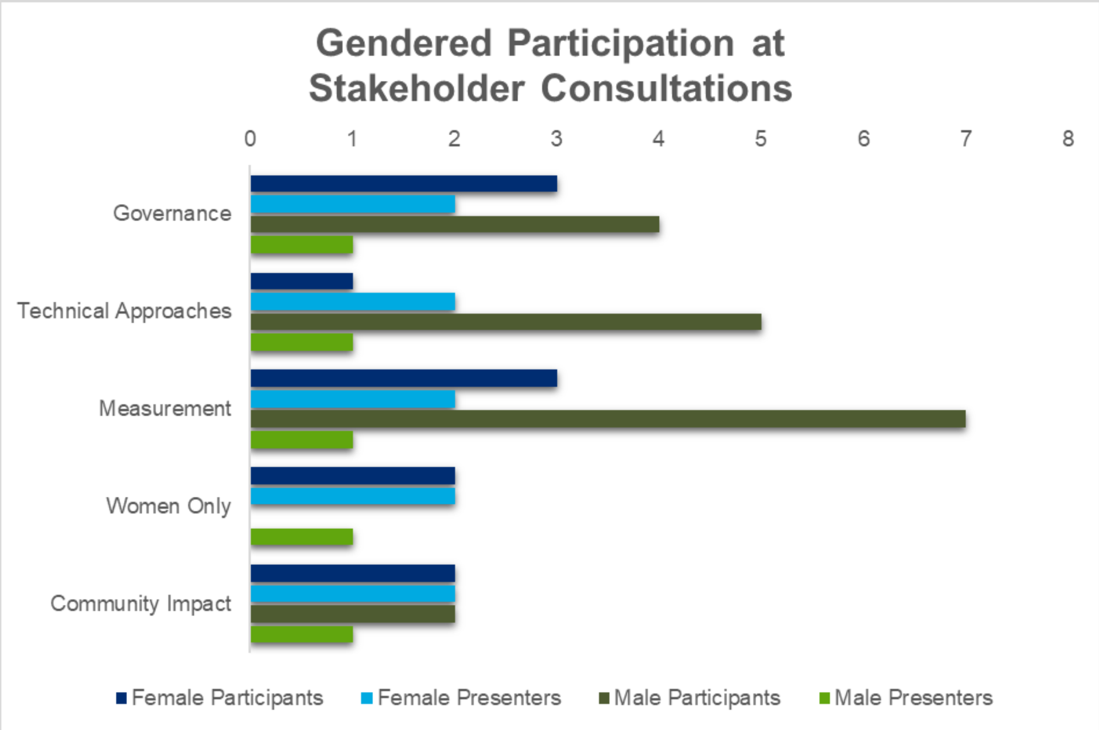

Figure 28 Gendered participation in stakeholder consultations

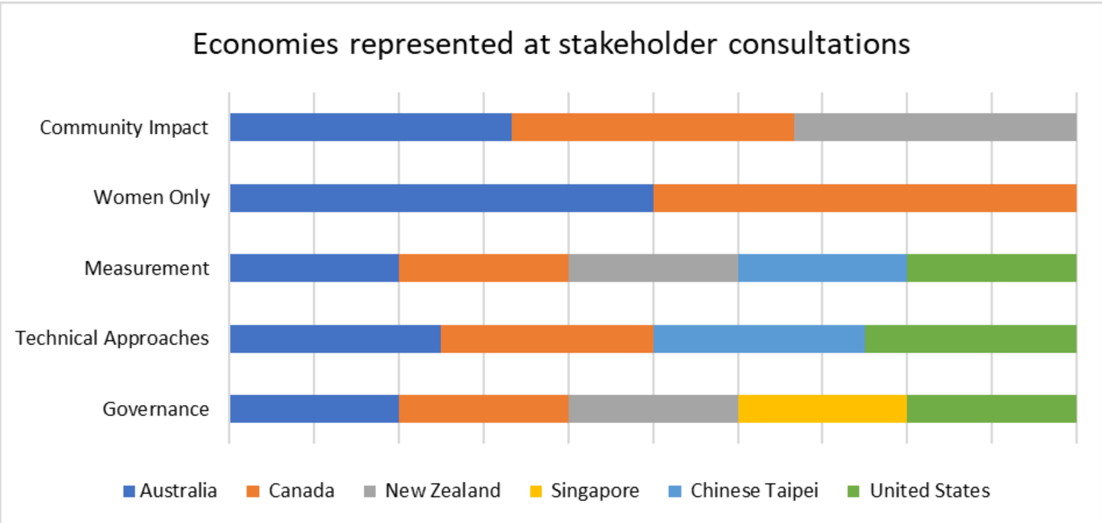

Figure 29 Economy representation at stakeholder consultations

MEETING SUMMARY: GOVERNANCE

The governance consultation meeting focused on regulation, licencing, and communication. A summary of the discussion is shown in Table 31.

Table 31 Meeting summary: Governance

<table>
<tr><th>Topic</th><th>Date</th><th>Participant Summary</th></tr>
<tr><td>RPA Noise Governance approaches (regulation, licencing, communication</td><td>22/11/2022</td><td>Seven participants (three women)
Three presenters (two women)
Five different economies – Australia; Canada; New Zealand; Singapore; United States</td></tr>
<tr><td>Key discussion topics</td><td colspan="2">Summary</td></tr>
<tr><td>RPA Noise problem and accountability</td><td colspan="2">Who is it a problem for?
• (NZ) – “There is an acceptable level of noise and each community is going to be different and each context is going to be different”
• (SGP) – “If it's a recreational use, then it would be more of the drone noise emission and on the community acceptance of what the noise levels are allowed.”
When is it a problem?
• Health safety impact
• Number of complaints
• Nuisance</td></tr>
<tr><td>Existing regulation</td><td colspan="2">Most economies have no dedicated RPA Noise Laws:
• Economies shared similar views in that general noise legislation exists, but nothing specifically focused on RPA noise. The exception was Australia which has RPA noise regulations for commercial use
• Multiple economies said that the issue was a problem for local councils, municipalities, or states
• (NZ) – “[it’s] more of an environmental issue owned by local councils. Councils will often defer to CAA”
• (CDA) – “we don't differentiate from commercial or recreational, so whatever we come up with it applies to everybody”</td></tr>
<tr><td>Regulation methods</td><td colspan="2">Licencing
• (SGP) “Licensing should be dependent on the activity. If it's a commercial operation, then it would be considered against the RPAS platform and the type of operations that it's allowed to carry out.”
RPA use or category
• How and if context should influence how RPA noise is managed
• Consideration of home-built RPA</td></tr>
<tr><td>Communication</td><td colspan="2">Self-Regulating Operators:
• It is in the commercial operator’s interest to comply and become accepted by the community in which they operate.</td></tr>
</table>

	• (AUS) "*Wing & Swoop are conscious of acceptance by community as their success depends on uptake"* • (AUS) "*Wing found dB level was not primary factor, rather the pitch. Interesting to consider for noise regs"* • (NZ) *"It's quite a proactive approach that we take. The same approach would have to apply for the use of drones. It comes down to an operator being mindful on what is involved and being mindful."* Communication Methods: • (CDA) – *"We have a full process for notifying regulatory changes"* • (AUS) "*Make it easy for users to stay within the rules. Easy 'how to' guides - don't hide the information in reams of legislation or technical information."* • Australia/Canada/Singapore all mentioned feedback through regulation consultation

MEETING SUMMARY: TECHNICAL APPROACHES

The technical approaches consultation meeting focused on noise forecasting and simulation, and engineering design. A summary of the discussion is shown in Table 32.

Table 32 Meeting summary: Technical approaches

Topic	**Date**	**Participant Summary**
RPA Noise Technical approaches	23/11/2022	Six participants (one woman) Three presenters (two women) Four different economies – Australia; Canada; Chinese Taipei; United States
Key discussion topics	Summary	
General noise technical approaches	Across various economies, there is no standardised method for dealing with noise problems. The response is varied but lies with the operator or is managed on a case-by-case basis.	
Noise Forecasting Models	Opportunity exists for near term & long-term noise forecasting models. Currently, member economies have little to no noise forecasting abilities or a desire to forecast. • (AUS) – *"Australian Noise Exposure Forecast (ANEF) and Australian Noise Exposure Index (ANEI) Charts"* • (US) – *"In the US, forecasting refers to the future scale of RPA use, estimation or prediction is used in a noise context."* • (CDA) – *"In Canada, there are currently no standards or regulations, which has prevented Canada from getting to forecasting. Right now, "Canada's RPAS industry is not thinking about noise whatsoever". Drone deliveries are targeting remote operations with typical flight paths over uninhabited areas so there is no focus upon noise. The CONOPS is constrained to a vertiport, rather than a backyard."* • (CDA) – "*Noise issue is delegated to municipalities.*"	
Noise Management Strategies	Economies differ in assessing and managing RPA noise impacts in either a case-by-case focus or through type certification. How is RPA Noise Dealt with? • (US) – "*Dealt on case-by-case assessment. Operator must define a 'nest area' where RPA will launch from. Operator will provide specific noise measurement data, ideally including data on take-off and delivery. There is no published guidance for RPA noise assessment. Noise is regulated, same as the traditional aircraft."* • (CDA) – "*RPA Noise is only a problem when it's a health problem. If it's not a health problem, it is a nuanced problem that comes down to municipalities or cities."* • (AUS) – "*Currently, there are no standards, but the majority of problems arise in the hover phase. The operator is ultimately responsible, who will try to tweak their drones to make it quieter."*	

	Concerns about restriction of new entrants: • (AUS) – *“Trials or temporary exemptions need to be available with appropriate communication to community, allowing operators to do measurements in the area they wish to operate.”* Engineering Approaches: What can authorities influence? Who is responsible? • (CDA) – “*The RPA manufacturer should be responsible and delegated through the authority. Noted that currently thinking too short term. In 5 years, there will be different scales and different operating conditions. Canada doesn’t differentiate between recreational and commercial aircraft. The definition of a model aircraft is still an RPA. They are also restricted to what they do.”* • (CDA) – “*Home built, or research-based drones are not a concern. Once the scale of production reaches a point of noise impact, it will become a fully commercialized product and be registered as such.”* Standardisation vs Type Certified • (CDA) – *“So here in Canada, we don’t [have RPA type certification]. An air taxi will absolutely need to be certified. Commercial drone delivery is not required to be certified. With a caveat that they cannot fly downtown of a city.”*

MEETING SUMMARY: MEASUREMENT

The measurement consultation meeting focused on techniques, approaches, and standards. A summary of the discussion is shown in Table 33.

Table 33 Meeting summary: Measurement

Topic	Date	Participant Summary
RPA Noise Measurement (approaches, techniques, and standards)	24/11/2022	Ten participants (three women) Three presenters (two women) Five economies – Australia; Canada; New Zealand; Chinese Taipei; United States
Key discussion topics	Summary	
Measurement approaches	• (US) - *Currently, it is evident that there are very limited measurement approaches in place. The United States uses available quantitative measurement. Measurement methodology has not been regulated and is mostly determined by operators.* • (US) - *The US does not regulate or require 1-second Leq data. When we conduct environmental analysis, we request 1-second Leq data at any microphone used. the US is working on measurements based on modifying the existing traditional aircraft methods to account for the operational and design characteristics of the sUAS aircraft* • (AUS) - *"Currently we don't require quantitative measurements (aside from number of complaints)"* • (CDA) – *"Currently nothing. Some research is being conducted using anechoic chambers simulating far-field conditions using microphone arrays."* • (NZ) – *"We don't have any measurements or standards…. It is possible that measurements are being done at local government / council level."*	
Regulation	• (AUS) - *"Manufacturer-met noise standards"* • (CDA) - *"RPAS Noise Standards"* • (US) - *"Currently, there are no RPA specific noise standards"*	
Communication	Complaint Types: • (AUS) - *"Complaints (in terms of numbers) counts"* • (CDA) - *"Canada captures drone sightings – including pilots who 'see' drones at 30,000 feet"* Other: • (AUS) - *"Would there need to be an independent verifier? (Avoid VW emissions scandal for example)"* • (AUS) - *"I wonder how much of the (reduction in) complainants is from noise tech reduction and how much is from improved community engagement?"* • (NZ) - *"That private organisations and companies might have done research themselves because they are interested from a social licensing perspective. They are likely to do the testing, as they are interested in going out and getting it. Rather than governments which are only interested in complaints."*	

MEETING SUMMARY: WOMEN ONLY

The women only consultation meeting explored any impact of being female or underrepresented and any barriers in relation to RPA. A summary of the discussion is shown in Table 34.

Table 34 Meeting summary: Women only

Topic	Date	Participant Summary
Women only working group (created for APEC gender inclusion targets)	25/11/2022	Two participants (two women) Three presenters (two women) Two economies – Australia; Canada
Key discussion topics	**Summary**	
Disproportionate Impacts	It was agreed among the participants that women are more likely to be disproportionately impacted by RPA noise for social, health and environmental reasons. This was discussed as being influenced by: • Women are more likely to be at home than men (potentially working from home, looking after children, or doing housework). As such, there may be a greater impact from noise impacts created during drone deliveries • Autoimmune issues often affect women, and also women are more likely to suffer ongoing health issues from COVID. Further investigation required into disabled people at home (women specifically) who might be affected disproportionately • (CDA) – *"Females as a group have greater hearing sensitivity, greater susceptibility to noise exposure at high frequencies, shorter latencies in their auditory brain-stem responses, more spontaneous otoacoustic emissions (SOAEs), and stronger click-evoked otoacoustic emissions than males as a group."* • (AUS) – *"Women escaping domestic violence may be hyper-sensitive to unusual noises"*	
Totally silent RPA	Zero-noise RPA may lead to unwanted misuse, such as stalking • Is completely silent RPA the end goal? Silent RPA may open the opportunity for stalking or other malicious actions. The reduction of RPA noise may lead to further impacts on women • Risks similar to silent electric cars, RPA that do not produce any auditory sound may have unwanted impacts on people with disabilities, such as walking into the RPA, or being startled • (AUS) - '*acoustically unobtrusive*' – if you try to listen to it, then you can hear it, but it doesn't drill it into your brain • Participants noted that the biggest complaints were about the particular tone of RPA, rather than how loud it was. This means that silent RPA doesn't have to be the aim	

Geofencing	Concerns were discussed around the impact of RPA geofencing on protected spaces (such as family violence shelters), and risk the location being identified. • Geofencing in an unmarked area, may allow for malicious individuals to reverse engineer and identify what is in the area. Investigation needed to determine how to safely implement geofences – random, sporadic geofences or no geofencing at all • Ensuring secure methods of recording locations, and reviewing needs for public facing code

MEETING SUMMARY: COMMUNITY IMPACT

The community impact consultation meeting explored accountability for RPA noise, impacts, safety, and methods of communication. A summary of the discussion is shown in Table 35.

Table 35 Meeting summary: Community impact

Topic	Date	Participant Summary
RPA Noise – Community impact and response	25/11/2022	Four participants (two women) Three presenters (two women) Three economies – Australia; Canada; New Zealand
Key discussion topics	Summary	
Influencing views	Influence of predominantly engineer perspective	
Defining when noise is a problem	Noise vs safety • (AUS) - "*Regulated (Civil Aviation) Safety but noise is traditionally a non-safety issue vs community issue*" • Safety related aviation regulations • When we consider safety for noise – we are typically concerned with physical safety (e.g., hearing damage) in mind • Psychological risks aren't usually included (ICAO mentions psych health concerning pilot safety and keeping aircraft in the air) At what point does RPA noise become a safety concern? • Physical damage (hearing loss) • (CDA) - "*Secondary safety concern as escalation method for psychological harm caused by repeated drone noise exposure (that's annoying)*"	
When should action be taken in response to RPA noise?	Complaints • Most note that complaints number is a key concern of authority • Complainant type and approach impacts the validity of the complaint	
Whose responsibility is it to manage RPA noise?	Discussion around the difference between a residential chainsaw and other noises and hobby drone operators	

SUMMARY OF INDUSTRY CONSULTATION

Representatives of the RPA industry were sought for consultation with this project. Co-sponsoring economies were relied upon to suggest industry stakeholders in their region who might be interested in participating. A particular effort was made to contact those companies that were mentioned as relevant by participants during other consultation tasks. Of those contacted, two companies responded to the invitation for an online discussion. One company is from Australia and the other is from New Zealand.

The type of work conducted by these two companies has limited overlap, aside from both being members of the RPA industry. As a result, two distinctly different industry perspectives were garnered. Two separate industry consultation meetings were held to explore each of these industry perspectives regarding RPA noise.

The industry meetings are summarised in the one table below, Table 36.

Table 36 Meeting summary: Industry

Topic	Dates	Participant Summary
Industry perspective on RPA noise	16/12/2022 19/12/2022	Five participants (four women) Five participants (four women)
Key discussion topics	Summary	
Noise Measurement	• Big companies can find funding for complex RPA noise measurement activities; however, it is difficult for small companies. The cost barrier should not be so prohibitive that only the big players are able to do the measurements • The noise produced by RPA is very different to normal aviation noise • With regards to RPA, you can have multiple tones, which is hard to capture. A single number doesn't account well for human perception; we need to use a combination of metrics • Adequately modelling the impact of RPA noise is a big problem to address. It requires a lot of resources to determine what is going to annoy people, and what counts as "quiet", and isn't something that can be done single-handedly	
Community impact	• The community don't seem to see noise as the fundamental problem, but more of a privacy issue and lack of knowledge • The local population become accustomed to the RPA noise as part of the soundscape over time • There are hours of operations and companies have a set of rules on when operations can be conducted • Each city/area has to be treated differently because the community is different. What is acceptable in one place, may not be elsewhere	
Community engagement, including complaints and feedback	• Noticed that outreach and education do mitigate for a lot. Answering questions up front about the operation is best to help educate and provide information • Feedback is encouraged and often helpful. We can often adjust our operations based on feedback and minimise or eliminate any negative impact to no detriment to our work. It is important to dive deeper into	

	the complaint to understand what is the complaint about, is it noise, height, hover or pitch? • Aviation noise is always a problem, but crewed aircraft fly over hundreds of people with little to no noise complaints. The cities have a mechanism to take noise feedback: direct reach out to the company and feedback also goes to the government. This works well and communities were happy they have somewhere to provide feedback/complaints • For the number of operations we conduct, the complaints are minimal • People want to know it is regulated even if it's not loud • For every city, (treat each differently) we provide noise feedback, compiled by direct feedback, feedback received by the city that they share with us. We look for patterns in data, categorise by suburb and describe feedback received and provide any follow-up
Governance	• Just by having a regulator, a lot of complaints are reduced. People have more confidence knowing there is a regulator • Cities have their own mechanism to deal with noise feedback. Helps to share data and strategies, which mitigate complaints • We think an economy-wide regulator is really important (not per city or state) for consistency. At the same time, a one-size-fits-all approach is not great. We want to ensure small companies are not disadvantaged • Talking about a drone flying around as a hobby, I can see this falling to the local group, managed by the local council. However, a delivery drone may not fall on that scale, it may be managed at an economy-wide level and local level. So, there should be some input from those levels too • If an RPA is loud enough to cause health problems, it’s different to privacy concerns. Noise and privacy should be treated similarly • A single number metric makes it easy to regulate but we don’t know the most appropriate metric; I don’t think anyone does
Noise Mitigation: Engineering Design and Operations	• The feedback was more about the pitch, which people found annoying and too loud • To try and reduce noise in our design, configurations, and propellers, we involved our engineer in the community engagement process. To help reduce the pitch/tone of the RPA, having that feedback was helpful • It’s hard to optimise propellers to reduce noise • As an operator we reduced the rotation speed which reduced the noise • Randomised routing is key – Uncrewed Traffic Management (UTM) system randomises routes and helps to reduce complaints/noise. It’s better to have a thousand different routes to the same destination than to fly over one house a thousand times
Identified Best Practice Methods (how)	• A proactive approach to community outreach and education has proven to be quite effective in managing expectations (including noise) • A collaborative approach with good communication between all stakeholders is key to creating systems that are fit for purpose • RPA flight operations should be spatially distributed to also distribute the impact of emissions such as noise
Identified Best Practice Processes (what)	• Community has the desire to know there is a management structure in place, even if there isn’t a problem • Creation of a clear, well-defined complaints process with feedback is essential

RECOMMENDATIONS

FOR REGULATORS AND INDUSTRY

This section summarises the identified RPA noise risks, issues, and opportunities for regulators and the industry to be aware of. These themes provide insight into areas that require additional attention and management[8].

Regulators are responsible for managing the existing policies and regulation, and those that it applies to. Industry is responsible for meeting the operational and design requirements, but also benefits if the current approach can be improved.

TESTING AND COMPLIANCE

Any regulatory requirement must be able to be measured against to show compliance. This is explored in Table 37, Table 38, Table 39, Table 40, and Table 41.

Table 37 Recommendations for data sets

Data sets	
Risk/Issue	It was accepted that to manage or mitigate RPA noise, measurement is required to understand baseline, operational, and problematic scenarios, however, databases of verified measurements do not currently exist. Challenges with accurately and reliably modelling RPA noise were identified. This is largely due to the scale of the problem: modelling the wide variety of operating behaviour across use cases and incorporating a 'typical' reaction to the noise produced were two recurring elements.
Opportunity	Measurement opportunities were identified particularly around a shared database of RPA noise data to enable regulatory decisions and estimated noise outputs based on RPA type. This data set is starting to be created as RPA noise is measured, particularly by manufacturers, across a range of models and propeller configurations. Data sets of recorded RPA noise and improved synthesized sounds were mentioned as opportunities, alongside advances in modelling capabilities and assumptions.

[8] References for these recommendations can be found in the Desktop Research Analysis references section.

Table 38 Recommendations for integration of data

Integration of data	
Risk/Issue	Difficulties exist in comparing community noise exposure responses due largely to the inconsistent metrics across the space: measurement techniques, questionnaires, collected data etc. Difficult to equate social surveys (how annoying the noise is) which are subjective with objective quantitative measurements unless they can be done simultaneously and instantaneously timestamped [51]. Difficulties integrating across authorities and other databases.
Opportunity	Importance of quality of recording and speaker/earphones Integration with other research findings and data sets should be central to the research design

Table 39 Recommendations for measurement equipment

Measurement equipment	
Risk/Issue	Time averaged testing can result in the mischaracterization of sound patterns, particularly for transient, or changing broadband behaviour.[6]. Typically, Class 1 microphones are used for noise certification and research testing of aircraft. The cost of these microphones may be prohibitive for typical measurements of inexpensive small UAS, especially if a larger channel count is required to capture the directivity and variability of multirotor UAS noise [6] This type of testing adds complexity for inexperienced entrants to the industry.
Opportunity	Improvements for measurement include [6]: • Offsetting the position of the microphone from the centre of a circular ground board or more complex “daisy petal” geometries to minimize edge diffraction effects • Larger ground boards maintain a flat frequency response across a wider range regardless of shape • The inverted microphone method is a close approximation to flush mounting over a frequency range determined by the spacing between the ground board and the microphone diaphragm When time-varying noise measurements are to be conducted, both lateral and longitudinal angles must be measured simultaneously, therefore requiring a planar acoustic array.

Table 40 Recommendations for measurement attributes

Measurement attributes	
Risk/Issue	The Doppler effect impacts noise measurement and capture due to the approach being different from recede levels [42]. There are operational instabilities in maintaining accurate hover [42]. Rotor and propeller noise is highly sensitive to changes in the aerodynamic operating condition, meaning no two flight passes will result in the same noise radiation pattern on the ground. This is an issue when measuring transient features but should average for static noise features with a sufficient sample size [42]. The variance in use cases creates difficulty in standardising testing procedures and measurement metrics. Temperature and wind gradients can result in measured sound levels being very different to those predicted from geometrical spreading and atmospheric absorption considerations alone. These differences may be as great as 20dB [6,10]
Opportunity	Attributes that should be measured include: • All flight states to characterise noise over the entire operating envelope [6] • Time variance of rotor broadband noise and modulation to better understand psychoacoustic impacts [42] • Identified objective psychoacoustic metrics [40], such as roughness, harshness, sharpness, and fluctuation strength. • Frequency and quantity of events in addition to event data [38]

Table 41 Recommendations for validation and calibration

Validation and Calibration	
Risk/Issue	Individuals were not always capable of differentiating between sounds well enough to make good use of a rating scale with fine resolution. [15] Anecdotes of impossible RPA sightings, or complainants with direct links to anti-RPA organisations, highlighted the challenges associated with managing the complaints process, particularly focussing on heavy resourcing requirements to evaluate the submissions. Using a reference sound makes everything referenced to that sound [15] Using language descriptors can experience issues with certain descriptors [15] Many studies have different measurement methods or definitions for identifying the relationship to sleep disturbance. When sound is measured in longer timeframes, a sleep disturbance may be incorrectly attributed [28]. Difficulty calibrating environments both controlled and uncontrolled [6] Putting someone in the chamber can lead to reactions and other attenuation [15].
Opportunity	Calibration can be achieved by checking for reactions with an impulsive test noise source, or by making measurements of spreading by the inverse square law [6]. Controlled test conditions: Semi-reverberant acoustic field is a realistic alternative to anechoic [6] Furnished rooms for testing: Similar calibration must be done for field testing, but it has the advantage of being easy to implement.

OPERATION AND DESIGN

Once requirements have been met, it is beneficial to maintain a positive relationship with the community and improve on areas that can cause an issue. This is explored in Table 42 and Table 43.

Table 42 Recommendations for social licence for regulators and industry

Social licence	
Risk/Issue	Social licence, being the ongoing acceptance and approval of stakeholders, including the local community, poses a challenge. This will evolve as the reputation of RPA, or 'drones', changes in the eyes of the public, and the technology is more widely adopted. Challenges were identified in maintaining the social licence, as well as the risk recreational or hobby operators pose, due to lack of oversight and exemption from applicable regulations, such as Australia's RPA Noise Regulations. Additionally, due to the increased proximity of RPA which operate at lower altitudes and the current community and industry operations challenges were identified around the impact of distraction and disturbance. Quantifying and verifying complaints was another metric that was explored, with many economies having existing processes. Anecdotes of impossible RPA sightings, or complainants with direct links to anti-RPA organisations, highlighted the challenges associated with managing the complaints process, particularly focusing on heavy resourcing requirements to evaluate the submissions.
Opportunity	Engagement with stakeholders including industry and the community was recognised as an opportunity for both regulatory bodies and commercial operators to build and maintain positive social licence. Reflective of the engagement spectrum from inform to empower (IAP2), Opportunities and Best Practice were identified for varying levels of stakeholder participation. Best practice recommendations included adopting a proactive approach to community engagement and education and engaging with communities feeling negatively impacted by RPA use, such as the example set by WING in Australia. Benefits can also be achieved by ensuring that relevant parties are connected and can enable data sharing where appropriate.

Table 43 Recommendations for technical approaches

Technical approaches	
Risk/Issue	Challenges were identified with hearing protection and noise limits both during operation and in event of failure, as well as the impact of quieter RPA if used for surveillance and the safety risks to vulnerable people.
Opportunity	Optimisation of propeller designs and noise forecasting models were specifically mentioned, however responsibility for advancing technical approaches and conducting research and development was delegated to manufacturers or interested third parties, instead of governing bodies within economies. A best practice example is WING, who redesigned their drones to lower the pitch based on in house research identifying that the pitch, rather than the decibels was a critical factor in many noise complaints.

FOR APEC ECONOMIES

APEC economies are responsible for setting policies, passing laws, engaging in international forums, and financing initiatives where appropriate. This section summarises the identified best practices for consideration by APEC economies[9].

GOVERNANCE SCOPE

Determining the appropriate scope of the governance measure requires consideration of the current situation, future needs, and clear definition of roles and responsibilities. This is explored in Table 44, Table 45, Table 46, and Table 47.

Table 44 Recommendations for determining metrics

Determining metrics	
Risk/Issue	Psychoacoustics recognizes that each person has a different response to a noise which can vary based on external and internal factors, as well as when they are asked to reflect on their opinion.
Opportunity	Consider limitations of research • Personal factors are constrained to those of the average person, meaning that only a limited number of subjects are protected by criteria which are developed from the assessment [50] • At high levels of low frequency noise (<100Hz), rating loudness and annoyance as equivalent begins to fail, meaning that measurements like dB(A) cannot predict annoyance [19]

Table 45 Recommendations for appropriate level of governance

Appropriate Level of Governance, Accountability, and Responsibility	
Risk/Issue	With different levels of government managing different aspects of RPA noise in different places, it gets harder to track and manage processes as the scales increase. Deferral of responsibility or accountability poses a risk to the entire RPA industry until policy clearly defines the responsible and accountable parties for relevant aspects. E.g., should the RPA manufacturer, operator, or both be held responsible for a negative noise impact? Enforcing rules and holding parties accountable for their (in)action will be necessary eventually.
Opportunity	An opportunity exists to have an economy-wide managed system with state and local government sub-chapters. Differentiation between RPA noise as an aviation issue or a “tool” as a domestic noise source may assist in more clearly defining responsible parties. Alignment opportunity between aviation and domestic noise issues, or alignment with privacy rules.

[9] References for these recommendations can be found in the Desktop Research Analysis references section.

	Most people do the right thing but the cases for misuse should also be considered. Consider similarities with other equipment like motor vehicles for personal transport.

Table 46 Recommendations for governance

Governance	
Risk/Issue	Both the survey responses and stakeholder consultations flagged a range of noise regulations and oversight, often overlapping, and multiple potentially relevant to RPA operation. This was discussed as leading to confusion for members of the community making complaints, and contradictory for the operators creating the noise. Assumptions were to be made about which regulations to follow and relevant governing authorities where overlap occurred. The impact of these existing noise governance approaches in each economy will require careful direction of specific RPA noise requirements, whether to overrule or align with those existing. Psychological safety impacts from constant annoyance is not currently considered in the same manner as risk to hearing damage.
Opportunity	Governance issues identified by participants provide an opportunity to improve the regulatory environment for RPA noise. Potential opportunities included clarity and communication about the respective responsibility of relevant authorities, integration across industry, operators, and overarching policies, and designing internationally accepted approaches for harmonisation. The respondents from the stakeholder meetings and survey responses spoke about existing and emerging practices which were being applied to RPA noise. Familiar approaches for each economy were more commonly used including general noise regulations, complaints and feedback processes, and aircraft and RPA regulations. Opportunities were discussed to expand these management and mitigation approaches, whilst also exploring new techniques that have been trialled by other economies. It was noted that local governments were typically best placed to manage recreational, or hobby RPA use due to their management of existing noise nuisance issues and land use planning. Specific approaches were also mentioned such as flight path and operating time restrictions to reduce impact and creating a measurement framework to understand RPA noise metrics.

Table 47 Recommendations for increasing scale and complexity

Increasing Scale and Complexity	
Risk/Issue	As the RPA industry develops, the scale of RPA increases in several aspects: • Number of RPA used in an operation • Frequency of operations conducted • Size of the RPA This adds a layer of complexity or increases the challenge of existing difficulties due to flow-on effects. This becomes especially apparent around effective communication with all stakeholders and data management/information sharing. Processes that work well now may not be as well suited to the scale of operations in 5 or 10 years (e.g., industry voluntarily reporting a log of community noise complaints to a government department is not a suitable long-term, large-scale solution).
Opportunity	An opportunity exists to future-proof systems by designing them with increased scale in mind. To accommodate the increased complexity, the ability of both regulators/policy makers and industry to be flexible and adapt to the needs of a rapidly changing environment and community feedback is highly desirable. Policy development needs to foresee this and allow flexibility.

STAKEHOLDERS

It is important to support any governance measure with collaboration and support for relevant stakeholders. This includes direct stakeholders who fall under the jurisdiction of the governance structure, as well as connected industries and related economies where a cohesive approach will support sector growth. This is explored in Table 48, Table 49, and Table 50.

Table 48 Recommendations for harmonisation

Harmonisation	
Risk/Issue	Industry can be restricted or delayed in their expansion into certain economies due to different regulations and requirements. Lessons learned and RPA noise knowledge are not currently shared.
Opportunity	Engage in international forums to enable a consistent approach across jurisdictions, and benefit from shared experience and learnings.

Table 49 Recommendations for social licence for APEC economies

Social licence	
Risk/Issue	Challenges were identified in maintaining the social licence, as well as the risk recreational or hobby operators pose due to lack of oversight and exemption from applicable regulations, such as Australia's RPA Noise Regulations.
Opportunity	Best practice recommendations included adopting a proactive approach to community engagement and education, as well as working with commercial RPA delivery companies to create noise regulations, engaging with communities feeling negatively impacted by RPA use, and engaging at all stages of a project lifecycle.

Table 50 Recommendations for financing

Financing	
Risk/Issue	Research and development is expensive without clear benefit or reason to undertake the task. Return on investment for a novel concept can be risky for industry organisations.
Opportunity	Initiatives to change existing practices need incentives and funding to create or transition existing roles, approaches, and knowledge. An example includes supporting the development of a monitoring framework, such as the Australian Noise Exposure Forecast (ANEF). • It is a system that is based on a modified version of the FAA Noise Exposure Forecast • The approach determines forecasted noise contours around an airport to depict exposure areas. • Flight schedules, paths, and aircraft type are factored into the forecasted contours.

FUTURE WORK

Throughout the project, items outside the scope of work were identified as beneficial to the understanding and maturation of RPA noise management.

The key items were:

- A limited number of industry stakeholders were engaged for this project purpose, a wider sample should be consulted for specific economy applications.
- Case studies applying RPA noise management regulation in an operational context.
- A case study of Australia’s RPA noise approval process.
- Links and collaboration with regulatory bodies and standards organisations internationally.

FRAMEWORK

Throughout this project, the framework has been referred to as the 'RPA Noise Framework', the 'RPA Noise Management Framework' and the 'Noise Management and Community Noise Impact Mitigation Framework'. Each of these titles is reflective of the framework, and for ease of reading, will be referred to as 'the framework' in this report.

Key terms are shown in Table 51 that are relevant to the framework section of this report.

Table 51 Glossary of terms

Term	Definition
Framework	A basic conceptional structure [1], that provides underlying support for the intended outcome
Outcomes-based	"Outcome-based regulation is generally considered to involve a focus on the achievement of specific regulatory outcomes… The proposed change in approach is seen as a response to a changing operating environment and of the need to reap benefits in terms of: • Increased due diligence, by requiring regulated parties to focus on achieving outcomes rather than fulfilling prescribed behaviours; • Providing regulatees with more flexibility to introduce new technologies, • Processes and procedures to enhance safety and reduce cost; and • Allowing the regulator to adjust to changing science, technology and economic conditions." [2]
Global harmonisation	"The concept of "harmonization" represents the development and adoption of the same standard or requirements. Harmonization may also be applied to procedures and practices so these are the same across economies. Harmonization represents an important means of achieving regulatory convergence over time, as does the adoption of common procedures and practices" [3]
Community	"The people living in one particular area or people who are considered as a unit because of their common interests, social group, or nationality" [4]
Best practices	"Methods or techniques that have consistently shown results superior to those achieved with other means, and that are used as a benchmark." [5]
Capability levels	"Level of training and skills" [6]
Consultation	"The act of exchanging information and opinions about something in order to reach a better understanding of it or to make a decision, or a meeting for this purpose" [7]

FRAMEWORK DESIGN RATIONALE

A framework is a basic conceptional structure [1], that provides underlying support for the intended outcome. These principles can be used to guide future development, approvals, communication, and review processes. This framework, however, is not intended to be prescriptive but instead allows flexibility for different contexts.

TARGET AUDIENCE AND SCOPE

The target audience for this RPA Noise Framework is primarily APEC economies which will be responsible for the design and implementation of the management strategies.

It is noted that industry, regulators, and other stakeholders are likely to use the framework to shape their understanding of the economy approaches, and this has been considered in the design.

FRAMEWORK OBJECTIVES

The objectives for this framework were informed by the project scope and fundamental expectations identified from the consultation process. Fundamental expectations from participants were considered equally with the project scope to ensure the culture and view for the industry were recognised.

The identified objectives have been categorised into the following three areas:

1. **Purpose of framework: Advance economy capacity to manage RPA noise**
   - "Enhance the capacity of all APEC economies to manage the noise impacts of RPA operations" (Project scope)
2. **Design of framework: Outcomes-based framework**
   - "Provide an outcomes-based noise framework which aligns with the interests and needs of all the APEC members" (Project scope)

Demonstrated by outcomes including:

- Management approaches should be as minimal as possible (i.e., do not unnecessarily over-regulate) (Fundamental expectation)
- Respective regulations should have appropriately accessible means of demonstrating compliance (e.g., do not require expensive testing which could restrict new entrants to the sector) (Fundamental expectation)
- The safety of both the community and operators is paramount (Fundamental expectation)

3. **Integration of framework outcomes: Global harmonisation**
   - "Encourage international harmonisation, which will support mutual recognition of RPA noise measurements and across economies" (Project scope)
   - "Promote harmonisation through consistent standards and recognised and transferable measurements" (Project scope)

From the identified framework objectives, Table 52 summarises how these have been considered in the framework design.

Table 52 Framework objectives

Objectives	Inclusion in the framework
1. **Purpose of framework: Advance economy capacity to manage RPA noise**	The framework provides the foundation to support RPA noise capacity enhancement, such as developing the policies, regulations, training programs, and technology needed to effectively manage the impact of drone noise on communities. This is achieved through communicating knowledge, best practice, being outcomes-based, and highlighting components needing consideration in any management approach. The outcomes-based framework helps to ensure that efforts are aligned towards achieving specific goals and objectives, and that progress towards these outcomes can be monitored and evaluated
2. **Design of framework: Outcomes-based framework**	Each of the framework components is designed to achieve a defined outcome, aligned with the outcomes-based approach. These components work together towards achieving the overall aim of a safe and acceptable impact from RPA noise.
3. **Integration of framework outcomes: Global harmonisation**	The framework supports global harmonisation by providing a common language and approaches to achieve shared goals across different economies. By focusing on specific outcomes and results, rather than prescriptive processes or regulations, an outcomes-based framework allows for flexibility and adaptation to local contexts while still ensuring the achievement of common goals.

METRICS

A typical outcomes-based framework defines metrics for resultant impacts to quantitatively determine whether a certain outcome has been achieved. Activity metrics, or measurements of outputs such as decibel level, are not used because they are not necessarily correlated with achieving desired outcomes and impede the flexible and non-prescriptive nature of the outcomes-based approach. Despite this, the conversation surrounding setting governance limits through defined metrics invites the need for further elaboration on their absence from the framework.

Whilst a predefined metric for RPA noise could provide a method for achieving consistency (if adopted by sufficient economies), it would be a blanket regulation, with no flexibility to account for the nuance of local context. This may result in a lack of consideration for the current noise environment, or the ability for the metric to be achieved at all. The challenge posed by setting a limit for one or more metrics has been demonstrated by management experiences in similar contexts:

- Experience relating to traffic noise, found that a decibel range "led to uncertainty about actual design targets levels (with proponents designing to meet the upper end of the range)" [8]
- Environmental noise globally, has been found to exceed existing limits [9,10]
- The WHO provides limits for specific environments, including locations, as well as activities, services, and events (e.g., festivals, hospitals, schools), however, note that these limits and standard measurement metrics are inappropriate where there are prominent low frequency components which instead would require reduced limits from those specified [11]

RESPONSIBILITY AND ACCOUNTABILITY

Responsibility and accountability for managing RPA noise was discussed in many of the consultation tasks for this project, with best practices included in the 'Recommendations' section of this report. This has not been included in the framework, primarily because it is a methodological consideration as opposed to an outcome. Additionally, local contexts will inform the resourcing and capability levels [10] which cannot be adequately condensed into a framework.

FRAMEWORK COMPONENTS

The primary outcome of this framework is defined as achieving ‘a safe and accepted impact from RPA noise’, whereupon the terms ‘safe’ and ‘accepted’ need to have agreed metrics determined by the economy and the industry.

The term ‘safe’ is defined as “free from harm or risk” [13] and in this context, refers to the acceptable level of noise exposure that does not pose a risk to human health or cause significant annoyance or disruption to daily activities. The safe level of RPA noise exposure may vary depending on the duration of exposure, the intensity of the noise, and the sensitivity of the affected population.

The term ‘accepted’ refers to the acceptance of safe RPA noise impact, and to achieving and maintaining social licence in the community.

To achieve an outcomes-based framework, the components need to represent defined outcomes resulting in the high-level categories appearing similarly to a stakeholder map:

- Healthy **community**
- Protected **workers**
- **Industry** growth and innovation
- Engagement and social licence

This approach allows clear objectives for each stakeholder group, whilst recognising that there may be similar considerations in approach. An example of clear objectives between the components is shown in how noise is typically managed between communities and industries. The industry is particularly concerned about “excessive noise” [14], whereas communities are more likely to have policies discussing “nuisance” or “unreasonable” noise [15].

The framework components were scoped to be easily understood and support differentiated levels of application for economy contexts. Economies with more established RPA industries or RPA noise approaches can expand upon framework components, as opposed to implementing initial steps.

Specific mention was made around vulnerable members of the community to ensure additional protections are considered and to raise awareness of participation bias in engagement practices which typically do not capture this subset of the population. Examples of vulnerable subgroups include individuals with certain medical conditions such as high blood pressure, those who are in hospital or rehabilitating at home, individuals performing complex cognitive tasks such as working or learning, the blind, people experiencing housing uncertainty, individuals with hearing impairments, babies and young children, and the elderly. Those with hearing impairments are particularly affected when it comes to speech intelligibility. Even slight hearing impairments in the high-frequency sound range can cause problems with speech perception in a noisy environment.

The impact of RPA noise on animals is out of scope for this project. However, it is noted that animal response anecdotally attributed to RPA noise can further impact the community. Examples include additional barking or disturbance to livestock [16]. Current evidence has not been sufficient to prove these impacts in the research [17], and as such has been excluded from having specific mention within the framework.

PROPOSED FRAMEWORK

The framework is shown in Figure 30, with outcome statements for each of the framework components shown in Table 53 and Table 54.

Figure 30 Proposed framework for managing and mitigating the community impact of RPA noise

Table 53 Framework component outcome statements Part 1

SAFE AND ACCEPTABLE IMPACT FROM RPA NOISE	The primary outcome of the framework is to achieve a safe and acceptable impact level from RPA noise. This is likely to differ across contexts within and between economies.		
HEALTHY COMMUNITY		**INDUSTRY GROWTH & INNOVATION**	
A healthy community where the impact of RPA noise does not detract from the health and well-being of its residents.		A maturing and supportive RPA industry, that has the resources to develop new technologies and practices that enable safer and less impactful operation of RPAs	
INDOOR AND OUTDOOR ENVIRONMENTS	Individuals and communities are safe from the negative impacts of RPA noise in both indoor and outdoor environments.	**EXISTING ORGANISATIONS**	Existing organisations in the RPA industry are supported to grow and develop, with recognition of the health and safety of workers and the broader community. To encourage innovation, flexibility in the approach taken to meet RPA noise outcomes is allowed.
CONSIDERATION FOR VULNERABLE POPULATIONS	A safe and healthy environment for all individuals, including those who may be more susceptible to the impact of RPA noise, or those with communication barriers.	**NEW ENTRANTS AND CAPABILITY EXPANSION**	New entrants to the RPA industry and existing organisations expanding their capabilities experience accessible and comprehensive support to ensure that they comply with RPA noise requirements and contribute to the overall growth and innovation of the industry.
LOCATION CONTEXT	Locations across the community are considered within the context of their land use, and reasonably expected noise levels.	**RESEARCH & DEVELOPMENT AND COLLABORATION**	Ongoing research and development into RPA noise reduction technologies and practices are actively pursued, with a focus on promoting innovation, collaborative partnerships and knowledge sharing, and continuous improvement within the industry.

Table 54 Framework component outcome statements Part 2

PROTECTED WORKERS		ENGAGEMENT AND SOCIAL LICENCE	
Workers in the RPA industry are valued, and their safety is prioritised, enabling a sustainable workforce into the future.		Engagement practices are sincerely undertaken to understand and work with all stakeholders, achieving social licence through mutual respect.	
SAFETY TO SPEAK	All members involved in the RPA industry can voice their concerns regarding RPA noise issues without fear of retribution or retaliation, ensuring a safe and transparent work environment.	**COMMUNITY**	Effective community engagement is practised across project lifecycles and is used to build trust and understanding. Accessible ways exist to facilitate the exchange of information and promote shared responsibility for managing RPA noise impact.
BEST PRACTICE RISK MANAGEMENT	Risk management practice involves identifying, assessing, and controlling potential risks to prevent harm or loss. This can include not only physical risks but also psychosocial risks such as stress and mental health issues. To effectively manage these risks, it's important to involve workers in the process and provide them with the resources and support they need to speak up about any concerns related to RPA noise issues.	**INDUSTRY STAKEHOLDERS**	Industry stakeholders are invited to be co-collaborators on RPA noise management approaches, including continuous improvement processes.
CLEAR UNDERSTANDING OF REQUIREMENTS	Workers clearly understand and follow RPA noise requirements, to maintain a safe and healthy working environment and a safe impact on the surrounding community.	**GLOBAL PARTNERS**	Knowledge sharing is practised globally, to communicate best practices, lessons learned, and emerging issues, and promote cohesion between economies.

IMPLEMENTATION OF FRAMEWORK

To support the implementation of the framework, an extract from "NSW Guidance for regulators to implement outcomes and risk-based regulation October 2016" [10] is included below and in Figure 31.

Outcomes and risk-based regulation provide regulators with a consistent and transparent framework to proactively respond to that challenge, while also increasing their effectiveness in achieving regulatory outcomes.

With sustained effort and support from the government, the move towards outcomes and risk-based regulation will enhance our collective economic and social wellbeing by:

- *Reducing the unnecessary regulatory burden on regulated entities*
- *Increasing the productivity of regulators and regulated entities, and*
- *Driving flow-on economic and social benefits.*

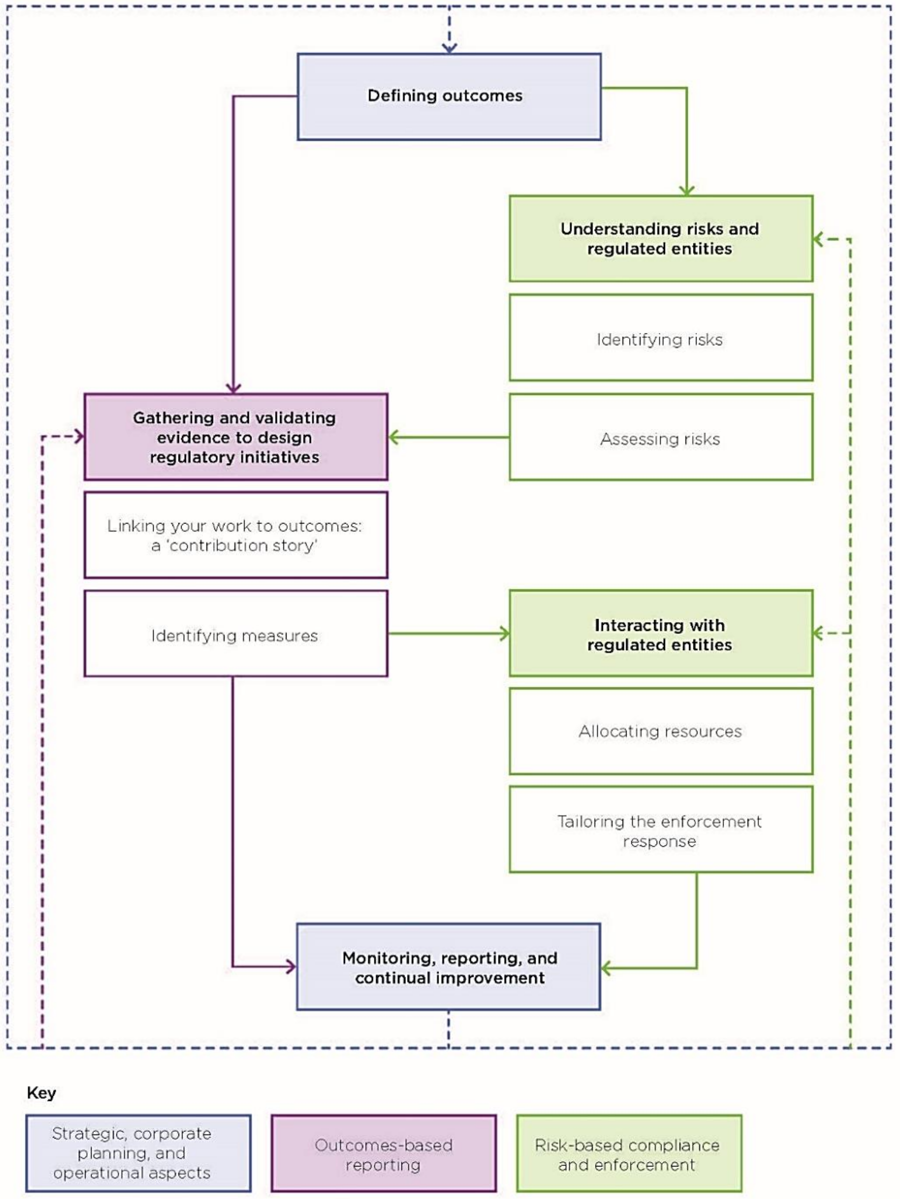

Figure 31 Outcomes and risk-based regulation framework

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CONCLUSION

This report has collated the project deliverables, provided insight for achieving harmonisation, discussed recommendations for regulators and industry as well as for APEC economies, and proposed a management framework for managing and mitigating the community impact of RPA noise.

The **comparison of economy regulations** relevant to RPA noise demonstrated:

- The majority of APEC economies differentiate between hobby and commercial RPA operators.
- RPA registration is typically required, with more economies requiring it for commercial operations.
- Australia is the only economy to have a specific complaint process for RPA noise.
- Six of the 21 economies have RPA noise work in progress, or future work planned.
- The majority of APEC economies have training or preparation requirements before the registration or licencing process.
- Community engagement, prior to changes occurring, was not shown to be consistent across economies.
- Nine of the 21 economies did not have an easily accessible or commonly understood process for general noise complaints.

The **stakeholder consultation** phase involved representation from eleven APEC economies and one non-member economy, in either a survey or working group. Female participation (excluding consultant presenters) across the surveys and stakeholder consultations averaged 32%, with individual engagement components ranging from 14% to 100%.

The overarching **fundamental expectations** for RPA noise management across economies was to ensure:

- The safety of both the community and operators is paramount
- Management approaches should be as minimal as possible (i.e., do not unnecessarily over-regulate)
- Respective regulations need to have appropriately accessible means of demonstrating compliance (e.g., do not require expensive testing which could restrict new entrants to the sector)

Recommendations for **regulators and industry** included:

- Considerations for achieving and maintaining social licence
- Technical approaches to improve RPA noise output
- Noise measurement considerations, including approaches, validation, calibration, and equipment
- Development and collaboration of data sets
- Ensuring the integration of data and research findings is considered in the research design

Recommendations for **APEC economies** included:

- Awareness and designing regulations for the future increase in scale and complexity
- Governance and appropriate levels of governance, accountability, and responsibility
- Harmonisation through engagement with other economies
- Financing and funding initiatives to support the development and growth of the sector
- Awareness of the limitations of research when determining metrics for regulation

The **proposed framework** (Figure 32) is structured using an outcomes-based approach to ensure that efforts are aligned towards achieving specific goals and objectives, and that progress towards these outcomes can be monitored and evaluated. This supports global harmonisation by providing a common language and approaches to achieve shared goals across different economies.

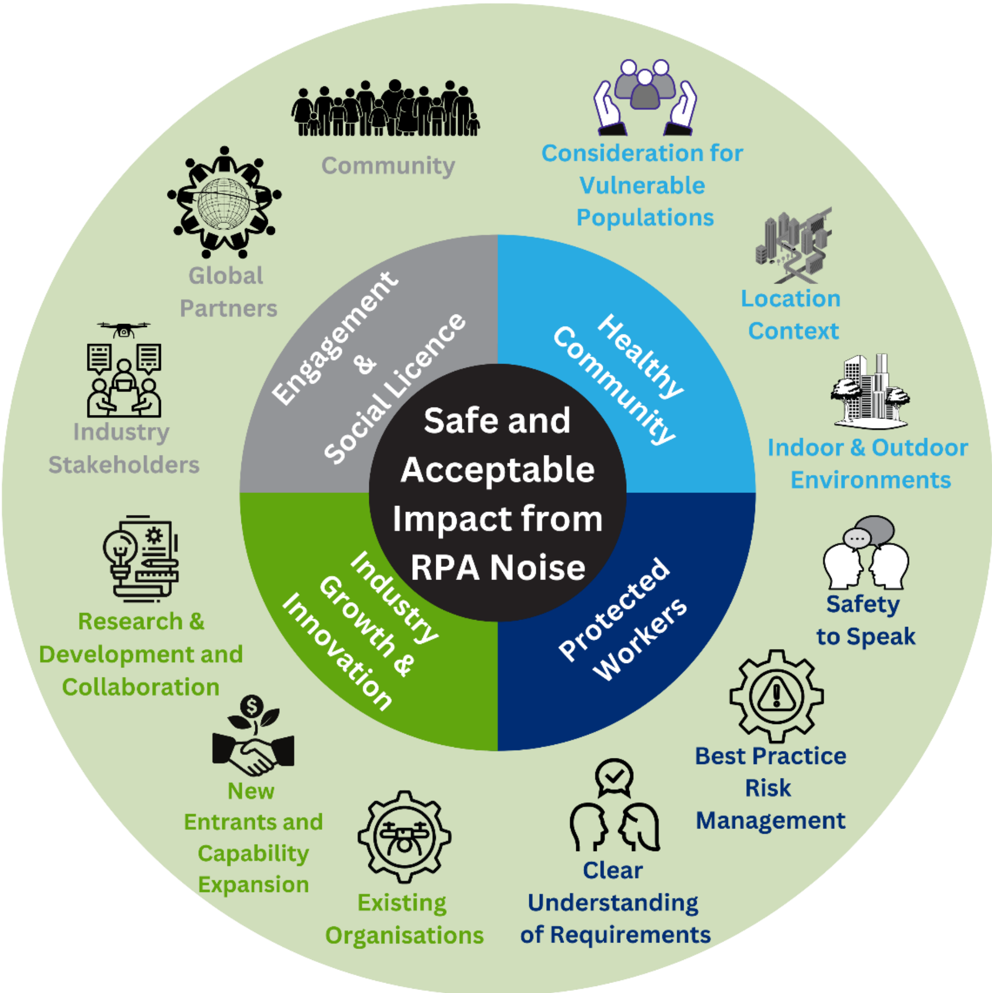

Figure 32 Proposed framework for managing and mitigating the community impact of RPA noise