University of Southern Queensland

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Analysis of the use of Drones for Structural Inspections to Assist Remote Construction – Focusing on Low/Mid Budget Drones

A dissertation submitted by

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DECLARATION: I declare that

• no part of this assignment has been copied from any other person’s work or from any other source except where due acknowledgment is made in the assignment, and

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Abstract

The Australian population is ever-growing, and with this, so is the distribution of its population. Construction in remote areas of Australia is a vital sector of the engineering and construction industry, but it comes with its own unique set of challenges. From the perspective of an engineer, a large portion of the challenges faced during remote construction revolves around the difficulty of not being on site. Engineers have several requirements when it comes to inspection, the main being thoroughness in their approach and assessment, thus completion of inspection remotely is far from favoured in the Australian construction industry.

Throughout Australia and the world, the popularity of unmanned aerial vehicles (UAVs) has skyrocketed. New models of drones are constantly being developed, so the question becomes, 'How can engineers in Australia utilize this technology to improve construction projects?' This study aims to answer that question.

Through real-time experimentation and testing, this research proposal has helped to determine how accurate drone imaging can be on varying stages and types of construction and whether its use can further improve the inspection process for remote areas of construction. Through the use of a low to mid-budget drone, several construction sites were visited to collect data, which was then analyzed to determine how effective of a tool this technology can become.

The study also used this experimental data to develop the foundation for future research to gain opinions and expertise of industry professionals, being engineers, certifiers, and contractors, to determine alternate views on this technology. This was completed by developing a survey for future use to outline what industry members think of this technology. Applying the opinions of others within the field is expected to better improve the understanding and acceptance that this technology presents, as well as outline the struggles it may face within the user operation side of the argument.

Upon the completion of these 2 datasets, a clear view has been constructed of;

(A) What aspects of construction can successfully use unmanned aerial vehicles to complete the required visual assessment?

(B) How will future research be able to gather professional opinions on the adoption and implementation of this technology, specifically how much pushback/acceptance may be expected from industry members? A view should be gained on what personal or practical issues may be faced for this technology to be further used in structural engineering and construction practices in the future.

The potential benefits of this expansion in knowledge and possible implementation of this technology are quite extensive. The implementation of drones for inspections is expected to have a major benefit on the efficiency and timeline management of construction progress in remote areas. It is also hoped their use can greatly reduce the expenses expected for contractors, engineers, and stakeholders, as well as provide a time-saving alternative for engineers themselves, and finally reduce the carbon footprint in the construction industry, thus creating a more sustainable and efficient industry for our future.

Introduction

Aim

The selected research project proposal aims to review and analyze the appropriateness of using unmanned aerial vehicles for structural inspections in construction within remote areas of Australia. UAV technology is improving greatly from year to year, yet it is not being utilized enough in the Australian construction industry, namely in remote areas where the preferred method of on-site inspection is difficult or costly. This proposal aims to expand on current knowledge and demonstrate how drones could improve the efficiency of a project for engineers, certifiers, builders, and stakeholders, as well as use experimental data to lay the foundation for future research with the development of a professional survey to garner industry opinion on this technology.

Background

Much like the rest of the world, Australia's population is on a constant rise. The Australian Bureau of Statistics reports a population increase of 1,008,939 people between September 2019 and March 2023 (Australian Bureau of Statistics, 2023). This equates to almost a 4% increase over 42 months.

As can be seen in Figure 1 below, the majority of Australia's population resides on the coast of the country, but with the constant rise in population, and the vast area of Australia's landscape, one can only expect that residential, commercial and industrial construction requirements in regional areas of Australia are going to follow the trend.

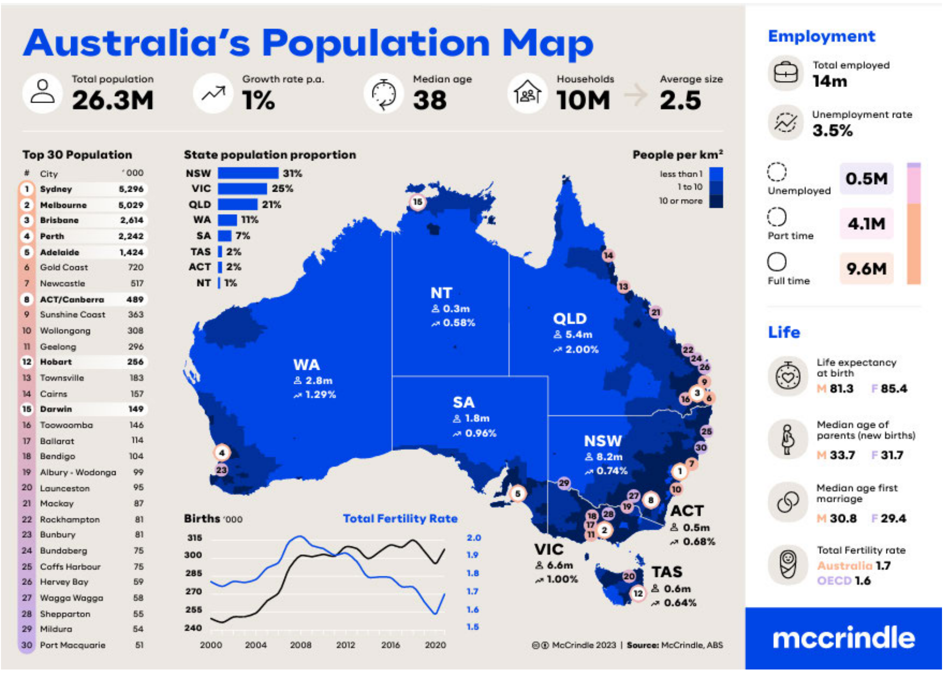

Figure 1 – Current Australia Population Data (McCrindle, ABS, 2023)

Although construction in remote areas of Australia is not a new concept, the efficiency of projects can always be improved. In regards to structural & civil engineering, one phase that can be adjusted to improve efficiency is the various stages of inspection required to have a structure comply with State and National requirements.

This project looks to assess the accuracy and appropriateness of the use of drones to make certain inspection stages more efficient and sustainable in remote areas.

Problems

Very little knowledge and data has been collected on the accuracy of drone video and photography in the construction environment, with even less data being collected in Australia, thus, the main problem this research aims to solve is whether or not a low-mid budget drone is a viable option to possibly complete structural inspections remotely.

The secondary problem that is to be addressed in future research is what acceptance/pushback this advancement in inspection methodology could receive from those within the construction community. This research will provide a stepping stone into this aspect through the development of an appropriate questionnaire and survey that utilizes previous literature and the first-hand experience gained through the experimental data collection.

Objectives

Objective 1: Accuracy

Complete experimentation and testing to determine the accuracy of drones as a data collection tool within construction projects and inspections.

Objective 2: Survey Development for Future Research

Develop an appropriate professional survey and gain the necessary approvals that would be required for future issuing to determine professional opinions.

Outcome and Implications

The intended outcomes of this research project are:

1- Gain a further understanding of the potential benefits of using UAVs in construction.
2- Expand the literature on the accuracy of drone imagery in construction projects.
3- Determine what types of inspection stages can see drones as a viable tool for data collection.
4- Provide a stepping stone for future research in determining professional opinions.

The potential implications that are expected to come from this research are:

1- To improve the efficiency of construction projects with higher difficulty of in-person inspection.

2- To reduce the expenses that can be caused by engineers required to travel long distances to complete in-person inspections in remote areas. These costs may be those of stakeholders, engineers themselves, or contractors.
3- To reduce the loss of time that can be felt by engineers having to travel long distances for projects.
4- To reduce the carbon footprint of the engineering/construction industry.

Literature Review

Established Knowledge

Challenges of Construction in Remote Australia

Several studies and journals have been published outlining the challenges faced in construction in remote areas. A study conducted by McAnulty & Baroudi outlined a number of these issues, first determining that many believe the contributing challenging factors to revolve around;

- Skills shortage – Attracting skilled workers in general, trade, and managerial roles becomes increasingly difficult in remote areas, as working in remote areas is often not an attractive alternative to employment in built-up areas of the country.
- Resource allocation – Equally as difficult as attracting workers, shipping materials long distances can increase costs and the risk of delays.
- Fly-In/Fly-Out and staff personal issues – FIFO work can often create additional concerns of worker fatigue and family issues. It is widely suggested that FIFO work "Contributes to higher instances of substance abuse, domestic violence, and parenting issues" (Storey 2001, McAnulty and Baroudi 2010).
- Productivity – Remote construction projects are often faced with productivity concerns. Leading causes of lack of productivity on such projects include alcohol abuse, homesickness, delay/shortage of materials, and environmental factors, such as extreme heat or rain.
- Infrastructure and communications – Lack of infrastructure in remote areas can lead to issues with lack of boarding for workers, minimal close-by materials, and issues with communication between the site and stakeholder locations.

The study by McAnulty & Baroudi aimed to provide evidence to support the above findings. To do this, a questionnaire was compiled to have industry professionals with remote construction experience rate particular statements regarding issues with remote construction projects.

The received results from the questionnaire confirmed the original research regarding the issues faced in remote construction. The use of a Likert scale for the survey shows that a large majority of the surveyed industry professionals agree on the major concerns for remote construction. These result tables can be found in Appendix 1.

The study also had survey participants rank the challenges identified. Figure 1 shows the findings with the vast majority of the concern coming from personnel, productivity, and procurement issues (McAnulty and Baroudi 2010).

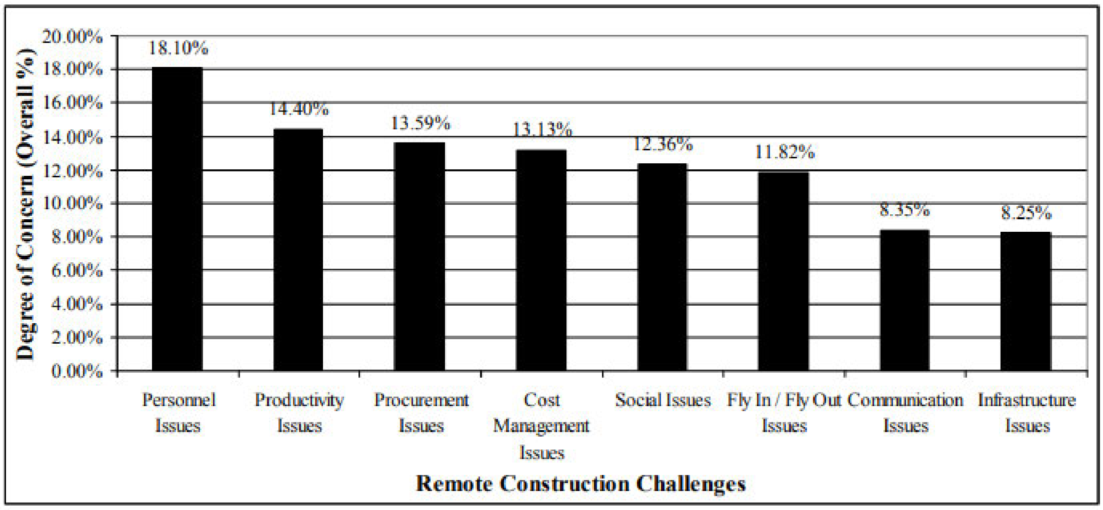

Figure 2 - Ranking of Challenges in Remote Construction Work (McAnulty and Baroudi 2010)

A case study completed in 2016 supports many of the findings of McAnulty & Baroudi. The case study was based on the Ceduna Hospital Redevelopment project approximately 776km from Adelaide, South Australia. The project was announced in 2008 and took nineteen and a half months to complete.

Members involved with the project were interviewed to get their opinions on the shortcomings and successes of the project. Trade management and site coordination were identified early in the project as being vastly important. A detailed and accurate building program had to be created to manage trade schedules and meet construction deadlines (Hay, Zuo et al. 2017). The other major issues faced were FIFO scheduling and constraints, material management, onsite morale, and keeping to the construction program. Surprisingly, it was found that labor sourcing was not a major concern faced, in a traditional sense. Finding tradesmen to complete the project wasn't a challenge, but often trades who specialize in remote work charged a higher rate, thus increasing the cost of the project. The challenge was also faced where small works required completion when FIFO tradesman were not on site. Interviewers outlined that this was combatted by making use of local trades and resources for smaller items that could be completed without the main construction team (Hay, Zuo et al. 2017).

Another report on the factors affecting remote construction was completed by Fien and Charlesworth. The article titled "'Why isn't it solved?': Factors affecting improvements in housing outcomes in remote Indigenous communities in Australia" focuses on the factors negatively affecting the design and construction of Indigenous housing in remote areas of Australia. The major factors outlined concerning remote construction are increased price of materials, transportation costs, shortage of tradespeople, lack of competition for tendering of work, higher labor costs, and greater costs of infrastructure (Fien and Charlesworth 2012). The report focused greatly on further concerns specific to Aboriginal communities, such as cultural and socio-demographic concerns. These concerns relate less to the issues of remoteness but are worth consideration within future construction projects.

Furthermore, a 2018 study completed by members of The Medical Journal of Australia outlined the psychological distress that remote mining and construction workers face in Australia. The investigation aimed to 'assess the prevalence and correlates of psychological distress in a sample of remote mining and construction workers in Australia' (Bowers, Lo et al. 2018). Through the use of an anonymous survey, a large number of remote employees across Western and Southern Australia provided data and opinions on the hardships and struggles that they encounter with working in remote areas. The major finding of the study was that 28% of the surveyed respondents had results showing high/very high psychological distress, a huge increase from the 10.8% for the overall Australian population. "The most frequently reported stressors were missing special events (86%), relationship problems with partners (68%), financial stress (62%), shift rosters (62%), and social isolation (60%)" (Bowers, Lo et al. 2018). Survey results tables can be found in Appendix 2 of this document.

Current Inspection Requirements and Procedures in Australia

Within Australia, each state and territory has its own building regulations in place. These building regulations are based on the requirements of the state-selected Building Act and the National Construction Code. The below table notes the regulations and acts that each of the major states and territories cite for construction and inspection requirements.

Table 1 Australian State and Territory Building Documentation

State/Territory	Act	Regulation
Queensland	Building Act 1975	Building Regulation 2021
Northern Territory	Building Act 1993	Building Regulations 1993
Victoria	Building Act 1993	Building Regulations 2018
Western Australia	Building Act 2011	Building Regulations 2012
New South Wales	Home Building Act 1989 Environmental Planning and Assessment Act 1979	Environmental Planning and Assessment Regulation 2021 Environmental Planning and Assessment (Development Certification and Fire Safety) Regulation 2021
South Australia	Planning, Development, and Infrastructure Act 2016	Planning, Development, and Infrastructure (General) Regulations 2017

Though all of these acts and regulations differ, they have several major similarities when it comes to the requirements for inspecting building works, particularly concerning the inspection of structural works.

All building regulations agree, that for Class 1a works, major stages of the construction must be inspected and approved before attempting to proceed. Outlined within all the building acts, the compulsory structural inspection stages for Class 1a works are;

1- Footings – After excavation of foundations, placement of formwork, and reinforcement.
2- Slab – After placement of formwork and reinforcement.
3- Reinforced Masonry – After reinforcement is installed.
4- Frame – Before cladding/sheeting of wall, floor, and roof framework.

When considering projects for class 2 to 10 buildings, the state/territory regulations often differ. In Queensland for instance, class 10 buildings only require a mandatory inspection at the final stages of construction, i.e. after construction is completed (Queensland 2021), whereas, class 2 through 9 buildings have different requirements. Inspections for these types of buildings are the responsibility of the assessing certifier, who must determine what stages require assessing to comply with the building development approval (Works 2023). Other states, such as the Northern Territory, require the abovementioned structural stages, 1-4, to be assessed for Class 1a, Class 2, and Class 10 buildings (Goverment 1993).

Although the separation of state and territory regulations can make the role of structural inspections complicated, a clear view can be gathered from the information and ideologies they share. Though from class to class the requirements for inspections differ, all the varying building regulations give a clear indication of what construction stages are the most imperative for structural inspections, thus, for this research project, excavation, reinforcement, and framework inspections will form the basis for data collection and review.

Current Procedure for Remote Inspections in Australia

Currently in Australia, the preferred inspection method for all aspects of construction is through in-person, on-site visual review. With this being said, some guidelines have been suggested for how certain off-site inspections can be completed.

In August 2020, in the wake of the COVID-19 pandemic, The Victorian Building Authority (VBA) issued a document titled "Guideline for the Conduct of Non-mandatory Remote Video Inspections (RVIs)". The document outlines a guideline approach for the use of video inspection in only 'non-mandatory' inspection scenarios and accounts only for "practical technology, personnel, safety and procedural requirements for RVIs to be conducted and does not consider any further advanced technology system (Victorian BuildingAuthority 2020). Importantly, the guidelines denote that RVIs should only complement traditional inspection methods on-site, not replace them in any way. " Adopting an RVI may aid in reducing the distance traveled and time savings for inspection, allow consultants to appraise construction elements and provide guidance more readily, or provide additional options for meeting contractual milestones. These guidelines are designed to aid in establishing RVIs within a suite of inspection, consultancy, monitoring and quality assurance services". The basic outline put forward by the VBA can be found below.

1- Principles
   a. Remote visual inspections are to be conducted via live feed, through the use of a compliant device. Compliant devices must have adequate camera quality and a reliable internet connection to allow for a reliable live feed. Meeting platforms and schedules need to be determined to allow for recording and viewing of the footage from off-site locations.
   b. On-site personnel are to be appropriately qualified in the area of work being inspected. Responsible persons conducting RVIs are to do so in a safe manner (multiple responsible persons may be required).
   c. The responsible person for inspecting is to effectively direct the on-site operators to ensure all required elements are viewed and inspected to allow for an inspection outcome determination.
   d. Documentation of inspection results should follow the normal process of an on-site inspection. A written determination of inspection results is required.

In the September following the Victorian Building Authorities issuing of their guidelines, the Australian Institute of Architects developed a response document. The institute's response outlines several recommendations for revisions to the guidelines, giving a clear outline of the opinions of professionals in the industry.

The first issue/recommendation that the document outlines is that “Governance of the practice from a contractual and professional practice perspective is not”. The Institute suggests that the wording and language within the guidelines places the burden on the architect, engineer, or surveyor but then does not support the authority of these members sufficiently. Much of these concerns stem from complications and difficulties that institute members have experienced when requesting to inspect building works and aspects (Australian Institute of Architects 2020). “The Guideline should, as far as guidelines generally can, promote the importance of non-mandatory inspections and promote a right of refusal by the responsible persons to refuse an RVI, redact a scheduled RVI or reject a conducted RVI and undertake an onsite re-inspection”.

Recommendations made by the institute to combat this concern are outlined in Figure 2 below.

Recommendation 1: That legislative changes are introduced to give effect to rights of responsible persons to request the undertaking of non-mandatory inspections of building works, including the methods to do so and the obligations upon responding parties.

Recommendation 2: That pursuant to the overall intent of Recommendation 1 that the draft Guideline line is strengthened to promote changes in culture and behaviours that support responsible persons to request non-mandatory inspections and control the methods to do so.

Recommendation 3: That Remote Video Inspections are carried out by an agreed competent independent third party,

Figure 3 - (Australian Institute of Architects 2020)

With the guideline being exactly that, a guideline only in its youth, the Institute outlined further recommendations to make the VBA recommendations a more comprehensive guide, with an additional built-in framework considering legislative issues, further determination of what non-mandatory inspections may be appropriate for RVIs and the requirements of training for those operating the remote visual inspection. Figure 2 outlines the recommendations made by the institute regarding these issues.

Recommendation 4. The current policy of not using remote video technology for mandatory inspections is maintained.

Recommendation 5. That Remote Video Inspection is only performed by persons who have undertaken a training program and have achieved a certified level of competency.

Recommendation 6. That the term, "Remote Video Observation is adopted instead of Remote Video Inspection to ensure the capability of video technology to undertake inspection is not overstated and the limitations of capturing both visual and non-visual information for the purpose of any inspections using video technology are understood.

Recommendation 7. Develop a robust policy framework and policy implementation steps to ensure the successful uptake and operation of RVIs in the Victorian construction sector which includes:

- **the draft Guideline and more comprehensively addressed legislative framework.**
- **a funded and evaluated pilot.**
- **industry practice education and support tools**
- **a risk and quality assurance and framework.**

Figure 4 - (Australian Institute of Architects 2020)

Finally, the AIA raised the importance of developing a larger policy framework for all states and territories within Australia. As previously discussed, regulations for building works vary from state to state, and thus a comprehensive and nationally accepted guideline and framework should be considered for remote visual inspections. As per this response, the AIA suggests that "consideration be given to developing a national Guideline for Remote Video Inspection within a national policy framework as part of the working program of the Building Ministers Forum and/or the Australian Building Code Board" (Australian Institute of Architects 2020).

Use of UAVs in Construction and Inspection

A group based out of the Hong Kong Polytechnic University completed a study on the "Application of drones in the architecture, engineering, and construction (AEC) industry". Within this study, a scientometric review of journal articles published from 1979 to 2021 was completed to determine the trends in research into drone usage in architecture, engineering, and construction worldwide (Nwaogu, Yang et al. 2023). A market survey was also completed to compile the article.

The scientometric journal review found that the majority of cited, peer-reviewed journal articles came out of the United States. The research showed that of the 16 most cited authors completing research on drones in the AEC industry, 11 were based out of American institutions. Following behind was Portugal, with 2, and China, Australia, and the United Kingdom with a single regularly cited author.

Author	Institution	Number of documents	Number of citations
Greenwood William W.	MathWorks, 1 Apple Hill Dr., Natick, MA, USA	2	74
Lynch Jerome P.	Dept. of Civil and Environmental Engineering, Univ. of Michigan, USA	2	74
Zekkos Dimitrios	Dept. of Civil and Environmental Engineering, Univ. of California, United States	2	74
Gheisari Masoud	M.E Rinker Sr School of Construction Management, University of Florida, Gainesville, Fl 32,611–5703, USA	5	70
Abrishami s.	School of Civil Engineering and Surveying, University of Portsmouth, Portsmouth, UK	2	34
Hosseini M. Reza	School of Architecture and Built Environment, Deakin University, Geelong, Victoria, Australia	2	34
Albeaino Gilles	Rinker School of Construction Management, University of Florida, Gainesville, FL, USA	2	26
Kamat Vineet R.	Dept. of Civil and Environmental Engineering, Univ. of Michigan, MI, United States	2	84
Kim Daeho	Dept. of Civil and Environmental Engineering, Univ. of Michigan, USA	2	84
Lee SangHyun	Dept. of Civil and Environmental Engineering, Univ. of Michigan, USA	2	84
Falorca Jorge F.	Department of Civil Engineering and Architecture, University of Beira Interior, Faculdade de Engenharia, Calçada Fonte do Lameiro, Covilhã, Portugal	2	2
Lanzinha Joãs Carlos G.	Department of Civil Engineering and Architecture, University of Beira Interior, Faculdade de Engenharia, Calçada Fonte do Lameiro, Covilhã, Portugal	2	2
Seo Junwon	Department of Civil and Environmental Engineering, South Dakota State University, Brookings, USA	3	168
Zhang J.	School of Automation, Northwestern Polytechnic University, Xi'an, China	3	21
Duque Luis	Department of Civil and Environmental Engineering, South Dakota State University, Brookings, USA	2	119
Jeelani Idris	M.E Rinker Sr School of Construction Management, University of Florida, Gainesville, Fl 32,611–5703, USA	2	6

Table 2 - 'Authors whose works are leading drone research in the AEC industry' (Nwaogu, Yang et al. 2023).

Furthermore, the review was able to determine the main research leading countries into drone usage in the AEC industry, by further investigating the overall number of articles and research documents produced by 2021. Unsurprisingly again, the United States lead all others by some margin. As can be seen in Table 3, China and the UK again lead Australia in several documents published within the field.

Country	Documents	Citations	Total Link Strength	% of Citation
United States	46	1194	20	38.8
China	18	135	13	4.4
United Kingdom	14	88	13	2.9
Australia	11	389	8	12.6
Canada	4	72	8	2.3
Singapore	3	2	8	0.1
Mexico	2	11	7	0.4
Nigeria	2	0	7	0.0
Iran	4	75	5	2.4
Spain	10	312	5	10.1
Brazil	6	122	3	4.0
Chile	2	22	2	0.7
Germany	3	501	2	16.3
Malaysia	2	0	2	0.0
Viet Nam	2	19	2	0.6
Italy	5	27	1	0.9
Japan	2	4	1	0.1
Poland	2	1	1	0.0
Portugal	4	7	1	0.2
Russian Federation	3	2	1	0.1
South Africa	2	1	1	0.0
South Korea	6	97	1	3.1
Switzerland	2	12	0	0.4

Table 3 - "Participation of countries in drone research and application within the AEC" (Nwaogu, Yang et al. 2023).

The article then goes on to research and determine the interest areas for drone application in the AEC industry, which provides a very interesting insight into the regional usage and research that has been undertaken within the sector. For Australia, the main research interests revolve mainly around safety management and the barriers to implementation of drone usage in the AEC industry. In comparison, the other regions selected showed a much broader interest demographic in the research being conducted. Areas such as risk assessment, digitalization of construction processes, and structural assessment have been discussed and researched throughout America, Asia, and Europe. Australia was determined to have fallen behind these other areas, as quoted “Unlike in Australia, research interests in America, Asia, and Europe have explored drone practicability in various areas such as inspection, defect assessment, progress monitoring and site mapping. Researchers in Australia could do more empirical studies investigating the use of drones in quality management” (Nwaogu, Yang et al. 2023). This can be further outlined within the following figures, in which the key research areas for each region were documented and graphically displayed.

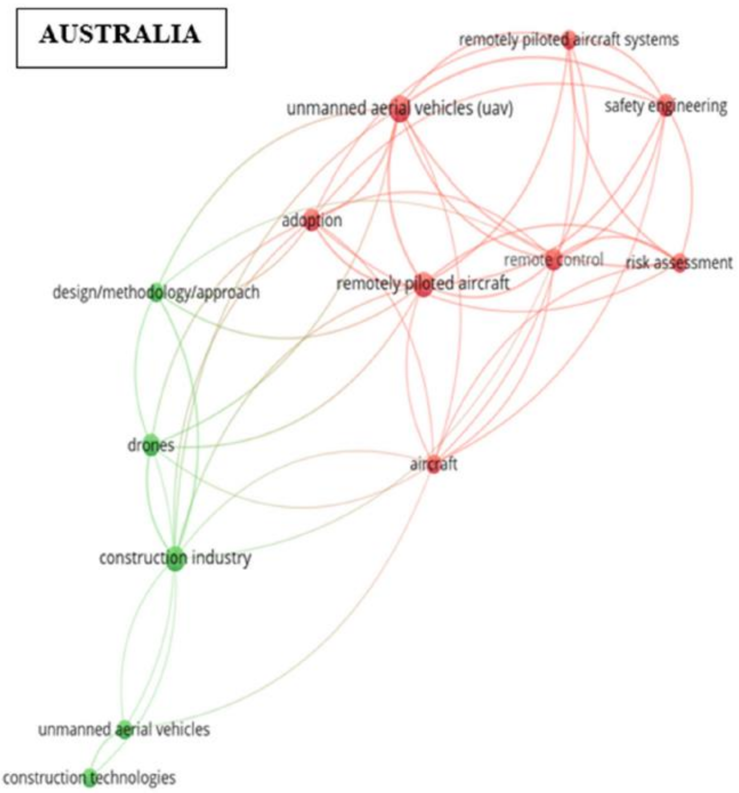

Figure 5 - "Regional research interest (Australia) for drone application within the AEC industry." (Nwaogu, Yang et al. 2023).

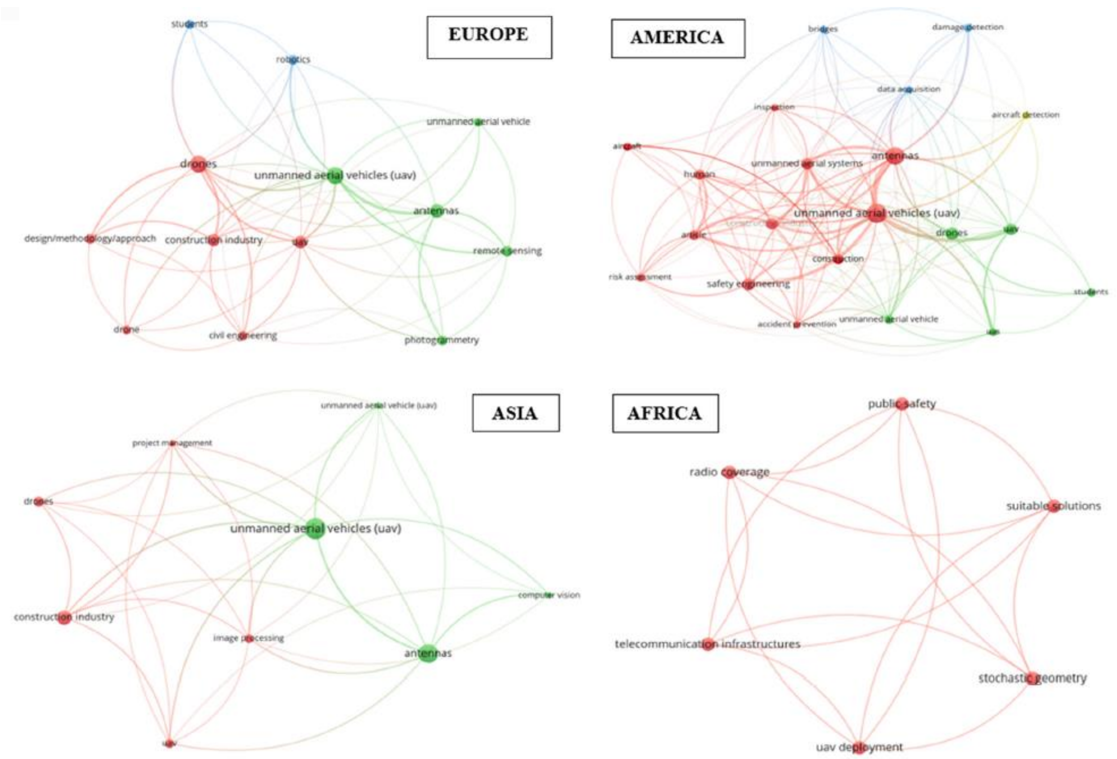

Figure 6 – "Regional research interest for drone application within the AEC industry based on keyword analysis." (Nwaogu, Yang et al. 2023).

Supporting the theory that the majority of drone usage in construction revolves around their use as a tool for monitoring inspections for maintenance and preservation of structures is a conference paper written by E Ciampa, which outlines the practical issues and benefits regarding the use of drones for these types of inspections, making use of 2 case studies to do so. The case studies selected were of 2 bridges that were inspected for defects. The first, constructed in 2017, was scanned using drone imagery to check the as-constructed dimensions of structural elements. The drone was also used to assess the condition. The imagery captured showed an error of 4.7-5.5% to the designed dimensions, which were determined to be in an acceptable range. The footage was also able to locate a water leak coming from under one of the abutment slabs. The second of the case studies was completed on a bridge built in the 1950s. This experimentation aimed to use the drone as a safe, fast, and inexpensive inspection data collection tool to determine defects in a much older bridge than the first case. The use of the drone allowed for the inspection of elements of the bridge without the use of a by-bridge, which would have required more workers to be involved, delays due to traffic stops, and additional safety risks. The data collected allowed members to determine major interest areas for further inspection and repairs, including a large location where concrete degradation was discovered, as shown in Figure 4.

Figure 7 - Case Study 2 Concrete Degradation (Ciampa, De Vito et al. 2019)

With the clear benefits outlined through these case studies, the issues and concerns that can come with drone inspections were also touched on as requiring future studies. The conference paper determined the main areas of concern with UAVs are;

- Certain qualifications required to pilot a drone, as well as the required permissions from relevant aviation authorities and property owners.
- Insurance and liability requirements.
- Mechanical malfunctions.
- Limited flight times.
- Weather conditions affecting drone flight and data clarity.
- Signal requirements.
- Lack of tactile ability.

Similar studies and experimentation can be found in abundance through search engines such as Google Scholar and Scopus. The table below compiles a number of studies that have been completed, determining that drone usage for damage and condition inspections is prevalent and effective.

Title	Authors	Summary	Result
Facade inspections with drones– theoretical analysis and exploratory tests	Jorge Furtado Falorca, João Carlos Gonçalves Lanzinha	3 buildings of varying ages were selected to examine the condition of façade coverings.	Drones are effective in assessing façade elements.
Drone-enabled bridge inspection methodology and application	Junwon Seo, Luis Duque, Jim Wacker (2018)	The glue-laminated bridge was inspected with a drone to assess the condition.	Drones are effective in assessing damage and condition of bridges.
Evaluating the Use of Drones for Timber Bridge Inspection	Junwon Seo, James P. Wacker, Luis Duque (2018)	Multiple structures were assessed, including reinforced masonry structures, timber footbridges, and large traffic bridges.	Drones are effective in assessing the damage and condition of all selected structures.
New trends in visual inspection of buildings and structures: Study for the use of drones	Falorca, Jorge Furtado, Miraldes, João P. N. D. and Lanzinha, João Carlos Gonçalves (2021)	Assessment of tall residential façade and clay brick chimney	Drones are effective in assessing the damage and condition of all selected structures
Inspection and Detection of Damages of Main Cable in Pathein Bridge Using Drone	Hegeir, O. A., Nagai, K., Matsumoto, K., & Mizutani, T. (2017)	Evaluating the slip of clamps and erosion of the main cable in damaged suspension bridges	Drones are effective in assessing damage and condition.
Towards UAV-based bridge inspection systems: a review and an application perspective	Brodie Chan, Hong Guan , Jun Jo and Michael Blumenstein (2015)	Evaluation of bridge conditions	Drones are effective in assessing damage and condition.

Table 4 - Case Studies Performed to Assess the Use of Drones for Condition and Damage Inspections

Furthermore, significantly less research has been completed on the use of UAVs for structural inspection and construction management. One study that reviews particular technological advancements in virtual and remote inspections has been completed by a group based out of Victoria. "Enabling technologies for remote and virtual inspection of building work" was published in 2023 and outlines some of the advancements in technology that could be used in inspection processes, including inspections of structural works. The study looks into several technologies, including those allowing for 3D scanning and virtual and augmented reality vision. The study has conducted a review of these advancements in technology to determine what particular technology best benefits inspection scenarios.

Through a review of previous studies, the article separates inspection scenarios into 6 groups, being boundary and excavation, reinforcement, framing, insulation, MEP (mechanical, electrical, and plumbing), and façade (Einizinab, Khoshelham et al. 2023).

Once again, the findings of this report outline that drones were most widely recognized as being effective for monitoring structure damage and condition, dominating the façade-based inspection scenarios. Many of these scenarios are related to the visualization and locating of defects. Table 4 summarises the other scenarios in which drones were deemed a useful data collection system.

Inspection Group	Inspected Item
Boundary and excavation	Slope deformation Pit wall slopes
Reinforcement	Cracking
Framing	N/a
Insulation	Thermal bridge - energy leaks
MEP	As-built to as-planned comparison

Table 5 - Drone Applicable Inspection Scenarios (Einizinab, Khoshelham et al. 2023).

In terms of mandatory structural inspection items, as discussed previously, the use of drones as the first choice in data collection was rare. A significant number of structural-based inspection scenarios were deemed to be better suited to stationary, wearable, and handheld data collection technologies. These technologies include laser scanning devices, as well as wearable augmented reality systems (Einizinab, Khoshelham et al. 2023).

The Australian construction industry is delayed in the adoption of these technologies, and it is suggested that the simple use of drones alone can be an effective and affordable method to streamline construction projects and inspection procedures when in remote areas of the country, as well as provide a stepping stone to further advancements in imagery scanning and 3D model building. The first step though is to provide analysis on the adoption of drones alone, as the Australian construction industry is falling behind others.

Knowledge Gap

Study Justification

There is an extensive knowledge gap within this research area to justify the completion of this project. The knowledge gaps found include;

1- Limited experimentation of drone images and video as a data collection tool in the Australian construction industry.

2- The current set of guidelines for remote inspections are limited to Victorian regulations, and non-mandatory inspections and do not include the use of unmanned aerial vehicle drones.
3- Limited analysis of expert opinion on the use of drones for inspections in Australia. Acceptance of this technology is expected to be one of the major factors affecting its adoption.

With these 3 major gaps within the current research, the proposed research project methodology will aim to further expand the study within Australia, and hopefully improve a major component of the construction industry by use of drone imagery and video to inspect structural items.

Methodology

Project Parameters

Scope

The scope of the selected proposed research project can be summarized by 2 main scope items, being:

1- Data collection.
2- Data accuracy analysis.
3- Professional survey development.

With the first 2 elements, the goal will be to determine the available accuracy of the gathered site data thus determining what areas/stages of construction can best benefit from the use of UAVs for structural inspections.

The final scope item will look to the further expansion of this research, with a survey developed and reviewed that can be utilized for future research.

Project Data Collection

Testing and Experimentation

The first major aspect of this research project will be to test the reliability and accuracy of drone footage on varying stages and types of construction projects. To complete this task, it is proposed that, with the use of an appropriate drone, several construction sites be selected to collect data on the varying aspects of a build to compile data and review how accurate and practical it may be to use UAVs as a data collection tool for structural engineering-based inspections.

Analysis of the images and video recorded by the drone will allow for an in-depth analysis of the information that can be gained using a drone without having to be on-site during the construction process. Once an acceptable number of sites and construction stages are investigated, an assessment will be able to be completed to determine what inspection types can be acceptably completed via the use of UAVs.

Many factors are going to need to be considered to allow for the completion of this testing and experimentation analysis, with the first being the selection of the required sites. To determine what sites are best, it must be determined what site data needs to be evaluated. Within the literature review section of this report, it was determined that the majority of Australian states and Territories regard mandatory inspection stages to be that of;

1- Footings – After excavation of foundations, placement of formwork, and reinforcement.
2- Slab – After placement of formwork and reinforcement.
3- Reinforced Masonry – After reinforcement is installed.
4- Frame – Before cladding/sheeting of wall, floor, and roof framework.

With these 4 aspects in mind, a selection of sites for experimentation can be completed to best provide data and footage for analysis.

Access to sites will be relatively easy to complete. Current personal employment at a civil and structural engineering organization allows for regular visits to varying sites for real-world inspections, complying with the above-outlined required stages. With this access, imagery can be taken during employment inspections.

As an alternative, if access to construction projects proves difficult, there is no shortage of personal contacts that will allow for access to constructed structures that will serve as adequate sites for data collection and experimentation. A significant number of agricultural structures can be accessed for data collection and assessment.

The second factor to be considered is the selection and procurement of an appropriate drone for data collection. Once again, access has been gained to a drone that has been deemed satisfactory in recording footage for experimentation and analysis. An overview of the provided drone specifications can be found below.

Drone specifications	
Brand and Model	Zero-X Pro Pulsar+
Resolution	4k UHD
Range	1000m / 450m for First-Person-View with smartphone or compatible VR Headset
Battery	3200mAh
Flight Time	28 minutes
Weight	612 grams

Table 6 - Drone Specifications (Source: Zero-X Australia)

Other features of the drone include inbuilt electronic image stabilization, advanced sensor technology, intelligent autopilot GPS, a 3-axis auto gimble, and a barometric sensor (Zero-X Australia, 2024).

Figure 8 - Zero-X Pro Pulsar+ Drone (Source: Zero-X Australia, 2024)

This model drone was selected based on several factors. The first and most obvious is the ease of access. Secondly, having already had experience with this model, learning to operate was not a concern, with several test flights being completed before the research period. This particular drone also serves as a realistic model that many, if not all, organizations could afford to purchase. The lightweight and HD footage is expected to be adequate to collect data and suits as a model that could be expected to be used on construction sites without the need for excessive licensing and training. With drones being so underutilized in construction, a lightweight option was determined to be the most accurate to portray a starting point for companies to develop skills and gain data for inspections.

The above-described data collection aspect methods have been selected because they are what is expected to allow for a high volume of high-quality experimentation to be completed. It allows for efficiency in collecting data for review and final analysis.

Expert Opinion

Stage two of this project methodology is to develop an appropriate survey for future issuing to gain the opinions and acceptance that may be expected with the implementation of this technology to help with remote construction projects. It was decided that surveys of 2 different groups would be required to provide the best demographic of responses. The first survey is to be aimed toward those completing the inspections, i.e. certifiers and engineers. The questions within this survey will be based on, using their expert knowledge and experience, how effective UAV technology could be in certain aspects of inspections. Questions will also aim to see how open professionals would be to both purchasing and learning about this new technology to improve their corporations and the engineering industry as a whole.

The second survey form will be aimed at those who would be on-site during the completion of these projects, being contractors of different varieties. This survey set will aim to contact builders and contractors of multiple disciplines to determine their opinions on drones as a viable inspection tool. This will be important, as in remote construction, these are the people who will likely be operating the drone and capturing the information for engineer review. Questions will be aimed again at both their opinions on how effective this could be, and their openness to develop the skills and understanding to possibly implement this technology.

Though 2 groups will be selected for surveying, the questions asked will be very similar for each group. This approach has been adopted to allow for analysis of opinions that, due to different involvement in construction projects, have a likelihood to be varying, allowing for a broad opinion analysis from different viewpoints to be completed. For the survey responses to best represent the construction industry as a whole, it is believed that the survey pool should be diverse in participant experience, tenure, and overall organization style.

The questionnaire is to be set up using the UniSQ survey tool and it is expected that relevant approval processes will be followed and completed.

Limitations

There will likely be several limitations faced during the completion of the research projects. These limitations can be found below.

1- Time - One of the biggest constraints in a project such as this is time. Though the exact due date for this report is not currently clear, the assumption can be made that all experimentation, data collection, analysis, presentation, and report writing will need to be done by approximately October 2024, giving a timeframe of roughly 1 year. Timeframes will need to be tightly managed so that all required information can be provided to the formal report within the allowed timeframe, while also balancing full-time employment and studies outside of the research project. To combat this, a project schedule will be developed, which can be found further in this report.

2- Access to Construction Sites - Within the year timeframe expressed above, experimentation of the accuracy of drone data collection will require access to construction sites to collect test data. Ideally, the construction sites visited would be of a large variety to allow for the best spread of the different stages of construction, as well as providing a broad range of project types that can be assessed. With the timeframe allowed though, access to a varying range of construction sites may be difficult to achieve, as there may not be a suitable site within a reasonable distance. The key to this will be to begin investigating possible construction sites that may be able to be accessed as early as possible, and thus give the best odds for increasing the variety of experiment locations. Current employment in structural engineering should allow for ample opportunity to visit sites.
3- Weather – The use of drones is limited by the weather conditions present on site. Many drones have requirements for maximum and minimum temperature and wind speeds at which drones can be safely used. Rain also poses a concern, with drones not being operable during rain events of any nature.
4- Drone Selection – There will be some limitations caused by the drone that has been selected. The main issues that are seen currently in the collection of data would be lack of battery time, though this can be managed as additional batteries are available, and the inability of this particular drone to live-stream footage to a meeting service. This though can be negated by the fact that experimentation at this stage will be based on the accuracy of footage, which does not require livestreaming.

Project Planning

Feasibility Analysis

For a project of this nature, it is important to ensure that all aspects of the report, including research, experimentation, analysis, and report writing can be completed within the allotted period. Careful consideration has been taken to determine if the time allowed is sufficient to complete the project. It is believed that if the items outlined in the limitations section of this document are addressed, completion within the time frame should be reasonably achievable.

Resource List

The below table outlines the list of resources that will be required to complete the data collection and analysis for the research project.

Item	Source	Cost	Comment
UAV Drone	Personal	N/A	N/A
PC with the required software	Personal	N/A	A personal laptop should provide all required.
Professional Survey Template	USQ Survey Tool	N/A	N/A
Tape Measure	Personal	N/A	N/A
PPE	Personal	N/A	N/A

Table 7 - Resource List

Schedule

January	February	March	April	May	June	July	August	September	October	November
Develop a detailed project plan and submit the proposal.		Conduct an in-depth literature review on inspection requirements in Australia, remote construction issues, the use of drones for construction and inspection								
Gain necessary approvals and permissions.		Finalize the research design and methodology.	Report Writing							
		Develop survey questions and submit for review from supervisor	Issue out surveys to relevant participants (builders, certifiers, engineers)		Compile and analyse survey response data.			Compare professional opinions with collected data to determine appropriateness and acceptance. Compile findings into a comprehensive report.	Review and finalize the report. Prepare a presentation summarizing key findings and recommendations.	
Compare USQ owned drone to employer owned drone to determine best fit for data collection		Drone experimentation and data collection in inspection scenarios. Can be completed through employment.								
Complete ePortfolio (unrelated to research project)										

Results and Data Analysis

Introduction

The main data collection method is experimentation-based, with the survey development forming a secondary aspect of the data collection. The experimentation aims to determine what information relevant to mandatory structural inspections can be gained through the use of UAVs, thus applying to remote construction requirements. The survey development intends to outline the requirements for the professional survey and provide a stepping stone to the collection of professional opinions on this technology. Both aspects are very important to determine how appropriate it may be to propose remote inspection technologies in Australia, and thus further advance the construction industry into the technological age.

Drone Imagery Data

A total of 5 sites were accessed during the course of the experimentation period. Sites were at varying stages of construction, with a broad array of complexity in their design and construction. Each site allowed for detailed flyovers to assess what footage could be gathered with the use of the selected drone. Each site has been detailed in the following sections.

Site 1

Description

Site one consisted of the foundation and slab elements for a large commercial shed with a length of 42m and a width of 20m. The associated slab and foundation design is imperative for a project like this, with the large scale of the structure imposing large loads that require transfer to the soil.

The construction process as follows for the slab and foundations was as follows.

1- Preparation of soil pad.
2- Drilling of bored pier foundation holes.
3- Pier reinforcement placed.
4- Pier concrete poured.
5- Slab reinforcement placed.
6- Slab concrete poured.

Inspection of the abovementioned items is important for a project such as this, with that large scale requiring careful consideration and management.

Conditions

The data collection was conducted during 2 low-wind days in close succession. Available sunlight was adequate to collect data. The site area was well maintained, with little to no obstacles in place, allowing for simple piloting from outside of the excavation site.

Imagery Collected and Analysis

The data collection on the site was completed during the foundation and slab construction stages. Data was collected during 1 approximately 11-minute, 30-second flyover, followed by a second 2-minute 30 flight using the Zero-X Pro Pulsar+. During the first flight, the pier layout and depths were assessed, and the condition of the footprint slab was captured. The second flight took place after the placement of slab reinforcement before concrete pouring. Specific details that were observed are outlined below, along with screenshots of the footage.

During the first flight, the footage was obtained to determine that the correct number of bored pier foundations had been excavated. As per the still below, it is clear that this is an easily completed task using the drone.

Figure 9 - Numerous Bored Piers Captured During Flyover

Next, it was deemed appropriate to test whether the depth of the bored piers could be assessed using the drone footage. Using the drone as a virtual assistant, pier depths were measured using a tape measure. The drone was then approached carefully at a safe distance and shown the measurement that was recorded. As can be seen in the following images, this proved an effective method, with the measurement being readable through the camera footage.

Figure 10 - Measuring of Bored Pier Depth

Figure 11 - Tape Measurement Reading 2100mm

Finally, the first flyover also allowed for the viewing of the cast-in bolts and reinforcement bars that are to be placed in the piers. Cast-in bolts are to be placed within the bored piers, tying the portal frame columns to the foundations, and the reinforcement bars are to be set within to provide additional strength to the concrete. Though these are not within the bored piers, next to each hole, the appropriate number of bars and the hold-down bolt systems can be viewed.

Figure 12 -Hold Down Bolts and Reinforcement Bars

The next flight to take place was completed to assess the slab reinforcement for the shed. Due to the large scale of the project, assessment of the slab reinforcement was an important factor before pouring was to commence. Several elements within the slab require assessment. Firstly, several joints, which are known as 'shrinkage joints', were to be placed in the slab, as per the engineered design. These joints allow for the slab to purposefully crack in specific locations, rather than randomly throughout the slab. To create this purposeful weak point, the slab mesh is to be appropriately cut. Every second wire in the slab mesh must be cut to create a point of weakness. Figure 13 shows an example of this, as was witnessed with the UAV. Support of the slab mesh can also be observed with the use of plastic chairs to ensure cover to steel. The waterproof membrane can also be assessed through the footage.

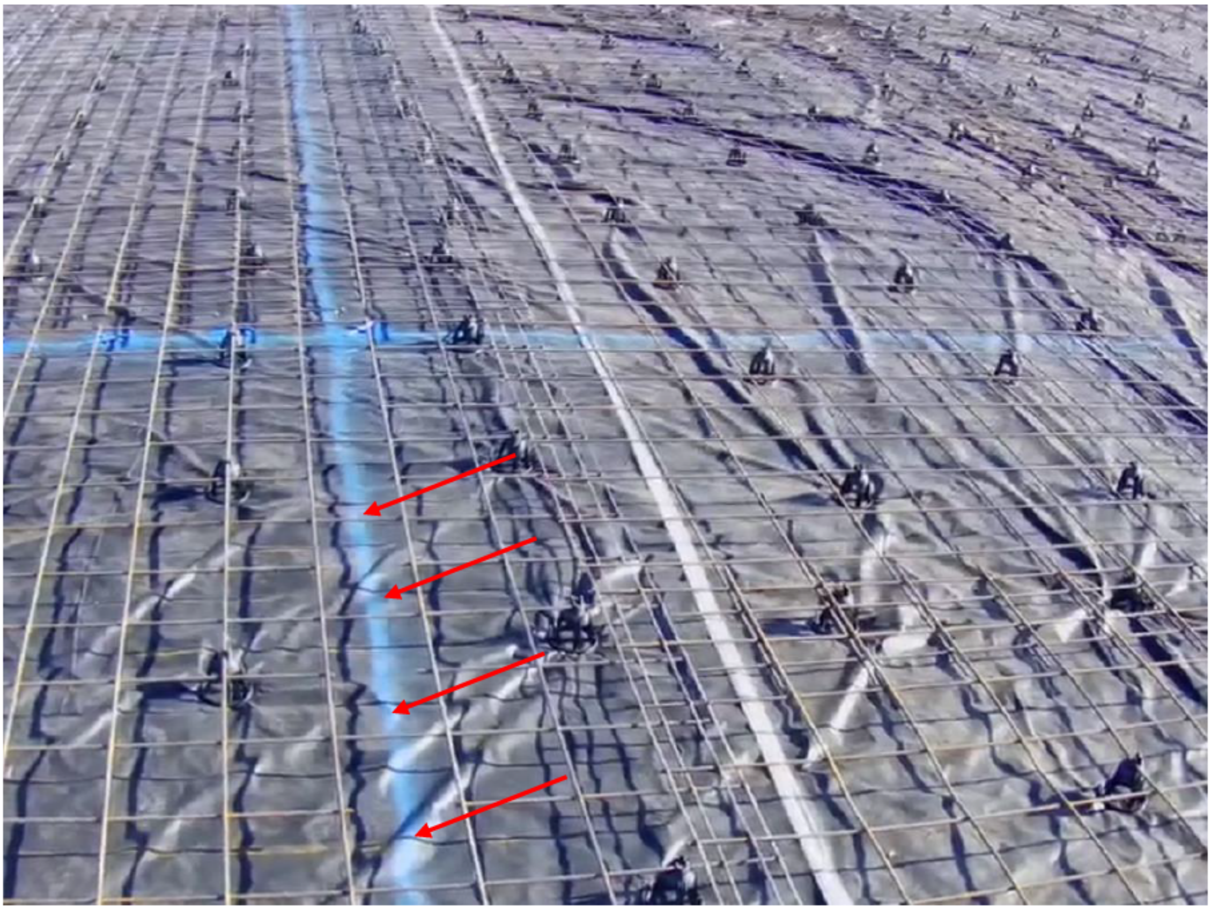

Figure 13 - Slab Mesh and Appropriate Joint Location

As the dimensions of the shed were quite large, it was deemed appropriate to install another style of joint that allowed for the slab concrete to be poured in 2 sequences. This joint is known as a construction joint, and they often require additional attention to ensure that the slab can still perform appropriately with the 2 halves being poured at separate times. Figure 14 shows this joint, with additional reinforcement for the required increased strength in the joint.

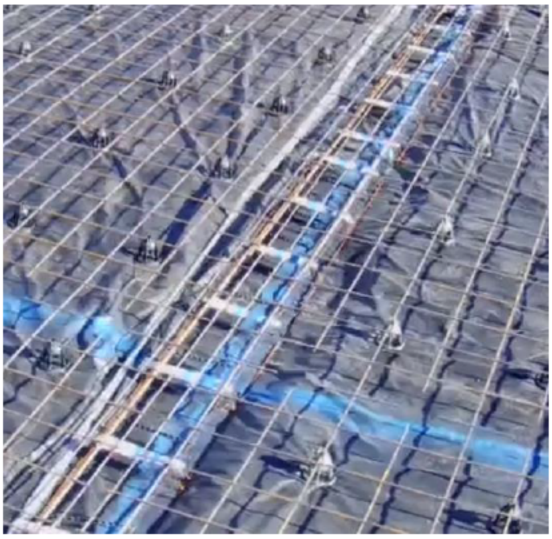

Figure 14 - Construction Joint

The final noteworthy item within the construction of the aforementioned slab relates to the localized slab thickenings throughout. A number of these thickenings were placed in the slab to support internal walls and point loads within the structure. These thickenings required additional mesh to be installed to the bottom. Figure 15 below shows 2 locations where thickenings for walls were added, and Figure 16 shows an example of the additional bottom mesh installed as required.

Figure 15 - Localised Slab Thickenings

Figure 16 - Additional Bottom Mesh to Thickening

Site 2

Description

Site two consisted of the foundation and slab elements for a new mid-scale residence. With approximate dimensions of in length of 24m by a width of 11m. The foundation system consisted of a raft slab style, with the construction process as follows.

1- Excavation of foundation beams.
2- Beam reinforcement placed.
3- Beam concrete poured.
4- Slab reinforcement placed.
5- Slab concrete poured.

As discussed earlier, inspection of these items is deemed mandatory in all Australian states and territories, thus outlining the importance of detailed assessment that the engineering design intent is followed.

Conditions

The flight was conducted during 2 low-wind days in close succession. Available sunlight wasn't ideal, with relative cloud cover observed with possible rain forecast later in the day. The site area was well maintained, with little to no obstacles in place, allowing for simple piloting from outside of the excavation site.

Imagery Collected and Analysis

The initial data collection on the site was completed during the foundation construction stage. Data was collected during an approximately 2-minute, 30-second flyover using the Zero-X Pro Pulsar+. During this first flight, the excavated foundations and their associated reinforcement were observed before the pouring of concrete. Specific details that were observed are outlined below, along with screenshots of the footage.

Figure 17 - General Layout of Foundation Excavation

Forming part of the inspection requirements for a residential foundation, the contractor's ability to correctly excavate the foundation arrangement is to be assessed, to ensure that the design intent is followed and that the number of beams and their spacing is as per the structural design plans. After a review of the design plans, the flight was completed to best capture important data that would be required to visually assess to complete the mandatory inspection.

As outlined in the caption, figure 17 outlines a series of stills taken from the UAV footage showing the general arrangement of the foundation beams for site 2. Though the stills only provide an example of the clarity of the footage, using an initial fly-by, a detailed assessment of the beam locations can be completed using the video footage, and thus can allow for confirmation that the documented beam arrangement has been correctly followed.

After the initial fly-over was completed, more detailed data was collected on the foundation system, with closer observations made, as shown below.

Figure 18 - Detailed Image of Foundation Intersection

Figure 18 shows a location where the foundation beams intersect, with reinforcement 'cages' running North-South and East-West. This imagery captured during the flight allows for a number of observations to be made, as outlined below.

Figure 19 - Notated Image of Foundation Intersection

As shown by the green lines, the cage is made up of 2 top reinforcement bars and 3 bottom bars. Though their size cannot be assessed in the image, the arrangement of the main reinforcement can be determined.

Shear ligs within the beam can also be observed, as shown in blue, with close spacing as required for standard residential foundation designs. Again, their size cannot be simply measured using the imagery, nor can the exact spacing, but the data is certainly clear enough to confirm their presence, and allow for an estimation of the spacing.

The next item that can be observed is the intersection lap bars. As a requirement of the design, top and bottom reinforcement bars are to appropriately lap at intersections where cage sets meet. As shown in red, a single top lap bar can be seen, indicating that the reinforcement bars on the left are appropriately tied and lapping with the bars to the right. Although only a single bar can be seen in this still, the continuous video footage allows for the other bars to be viewed. Size and specific length cannot be measured, but again, an estimate of the lap can be made, with reasonable assumptions allowing a determination of whether further confirmation is required.

The next still selected from the collected site 1 foundation data outlines a ‘T’ intersection in the foundation systems. As can be seen, the items outlined in Figure 19 can also be noted in Figure 20, with the added visual of the top and bottom intersection bars (blue). These bars are installed to tie cages together at corners and external intersections. Several plastic ‘chairs’ can also be observed (green), indicating that cages are appropriately supported off the ground. Finally, this figure also allows for a visual assessment of the ground conditions of the excavation. As indicated in red, it appears that some minor instability can be observed in the excavated soil. This serves as an example that a slight cave-in may have occurred. This cave-in may cause soil to fall within the excavation, compromising the reinforcement integrity and cover. Any fallen debris would require removal before pouring concrete.

Figure 20 - Notated Image of Foundation 'T' Intersection

Site 3

Description

Site 3 consisted of the slab stage for a new mid-scale residence. With approximate dimensions of in length of 22m by a width of 11m. The foundation system consisted of a raft slab style, with the construction process as follows.

1- Excavation of foundation beams.
2- Beam reinforcement placed.
3- Beam concrete poured.
4- Slab reinforcement placed.
5- Slab concrete poured.

As discussed earlier, inspection of these items is deemed mandatory in all Australian states and territories, thus outlining the importance of detailed assessment that the engineering design intent is followed.

Conditions

The flight was conducted during a sunny, low-wind day. The site area was well maintained, with little to no obstacles in place, allowing for simple piloting from outside of the building footprint.

Imagery Collected and Analysis

The data collection on the site was completed during the slab construction stage. Data was collected during an approximate 8-minute flight. During this first flight, the slab works and associated reinforcement were observed before pouring concrete. Specific details that were observed are outlined below, along with screenshots of the footage.

The first still of the captured video data selected allows for the assessment of several items. Firstly, it can be observed that an off-cut of reinforcement mesh has been left within the slab space. To maintain the integrity of the slab, it is best practice to have all off-cuts removed before pouring. The image also allows for the assessment of 2 different reinforcement mesh lap techniques, as highlighted in blue. Mesh lap is an important factor in the construction of concrete slabs, and the 2 methods observed can be assessed using the captured footage. Finally, this image shows a good representation of what is known as ‘starter bars’, as indicated in green. These are the reinforcement bars that tie the slab to the footings. Though their size and spacing cannot be determined, reasonable assumptions can be made, as can also be said for the reinforcing mesh.

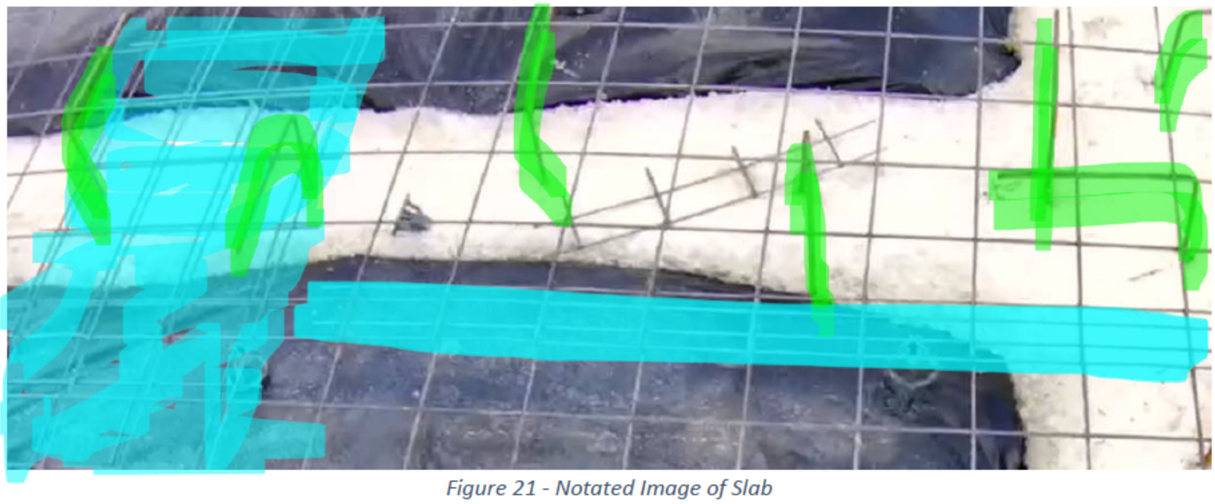

Figure 21 - Notated Image of Slab

Figure 22 allows for further analysis of the slab reinforcement installation. Within this still, it can be observed that additional reinforcement bars have been installed to what are known as 're-entrant corners'. This is where a slab changes direction and extends 90 degrees from its original alignment. These areas are weak spots in a slab and can be prone to cracking, thus, common practice is to install additional mesh at 45 degrees to the corner to provide further strength to the slab. The data captured by the drone allows for this additional reinforcement to be documented, and allows for a reasonable assumption on its size and length.

Figure 22 - Re-entrant Corner Slab Bars

These 're-entrant bars' are often also placed at the corners of areas where the slab is set down. Setdown areas often occur either where tiles are to be laid, thus creating a level threshold from tiled to non-tiled areas, or at outdoor areas to further improve water protection from internal and external areas. In Figure 23 below, these setdown corner bars can be seen in one area, but accompanying this is a wet area where the appropriate corner bars have not been installed. The drone data has allowed for the assessment of these areas and their appropriate reinforcement.

Figure 23 also provides some insight into the mesh requirements in these ‘setdown’ areas. Due to the slab being lower in these areas, the slab mesh must be lowered by the same amount to allow for the slab cover to be maintained. A basic sketch showing what this detail may look like can be found in Figure 24. The footage allows for a basic visual inspection of the mesh, with it being relatively reasonable to assume that a lower level of mesh has been placed (as shown in blue) and the required lap has been achieved. Figure 15 also provides a clear view of the slab mesh supports, known as ‘chairs’ as highlighted in yellow. These chairs ensure cover is maintained to the reinforcement steel. Finally, figure 23 below also allows for the observation of appropriate formwork to the outside of the slab.

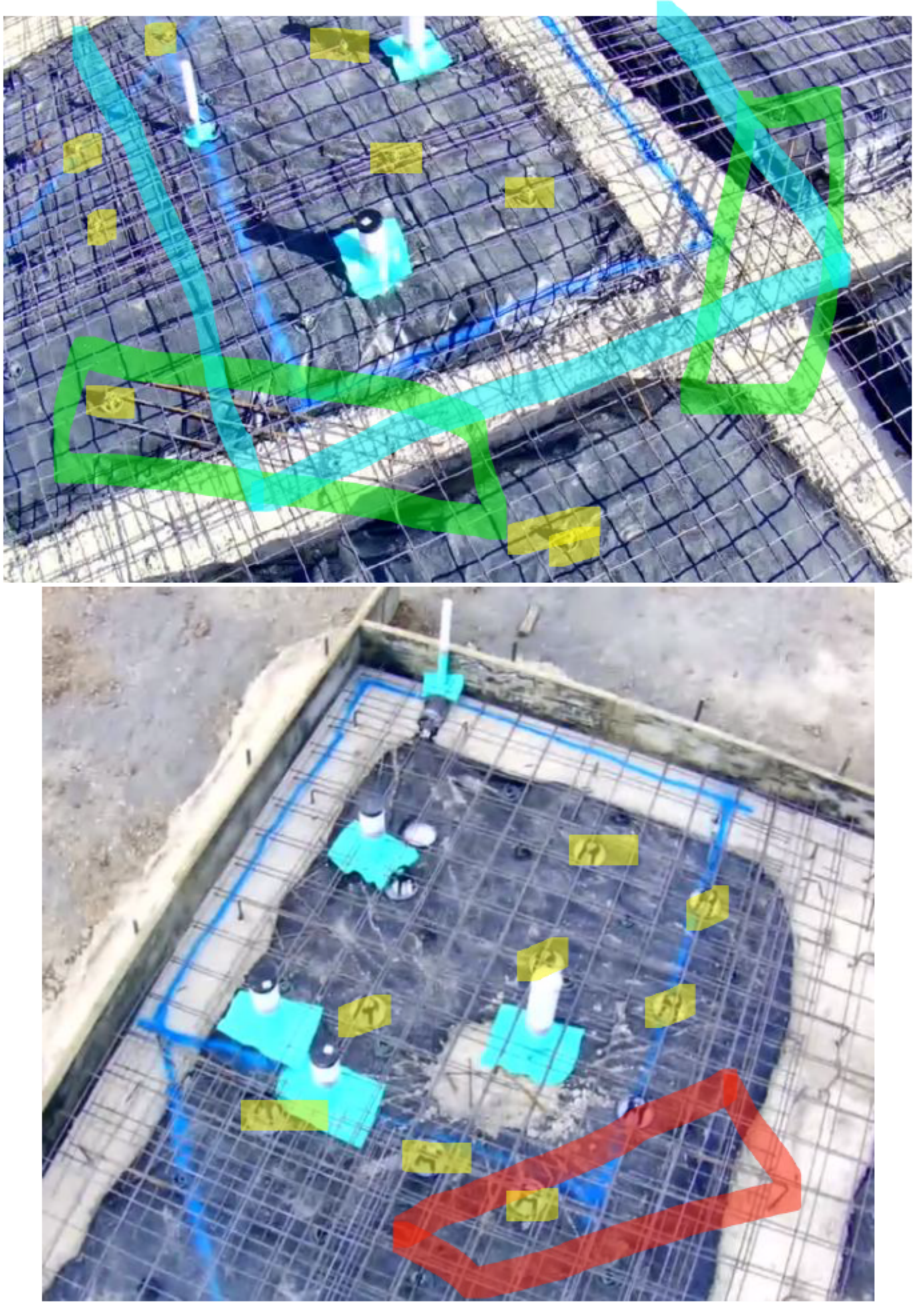

Figure 23 - Wet/TIle Setdown Areas

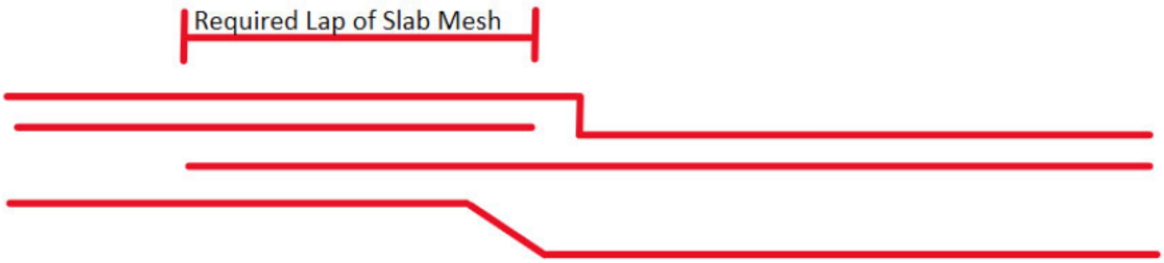

Figure 24 - Setdown Slab Mesh Detail

Finally, the abovementioned site 3 stills show numerous examples of the condition of the waterproofing that is required for this type of project. As is a requirement for residential slabs, a waterproof membrane is to be placed under the slab to protect the slab and reinforcement from rising damp. Waterproofing and protection are also required for all pipes installed in the slab. Both these items can be assessed using the recorded drone footage.

Figure 25 - Suitable Membrane Condition and Pipework Protection

Site 4

Description

Site 4 consisted of footage capturing of an in-situ timber framed 'farm shed'. With approximate dimensions of in length of 20m by a width of 9m. The structure consisted of an entirely timber-built frame of columns, trusses, purlins, and bracing.

This site allowed for a view of what data can be captured for framing elements of a structure, with frame inspections being a vital stage for most structures.

Conditions

The flight was conducted during a sunny, medium to high wind day, with the wind proving to be an obstacle, wanting to push the drone away from the intended flight path. The site area was well maintained, with little to no obstacles in place, allowing for simple piloting around and within the building.

Imagery Collected and Analysis

Data was collected during an approximate 2.5-minute flight. During this first flight, the members and the varying connections were observed, as outlined in the below stills taken from the flight.

From the still, in Figure 26, it can be observed that the building is constructed using several timber trusses, spaced evenly with timber battens or purlins spanning over the top of them to support the roof sheeting.

Looking more closely, several other important structural elements can be observed. As outlined in green, it appears the building has been fitted with tensioned metal straps to the underside of the roof battens. These are an important structural element as they provide rigidity to the building.

The next items that can be viewed are the varying connections of the trusses. Truss connections are made up using metal plates and varying bolts. Though the thicknesses and bolt sizes cannot be observed, the number of bolts and plate arrangements are quite clear in the captured footage.

Figure 26 - Farm Shed Front View

A still taken from another stage of the flight allows for a clearer view of the overall system supporting the trusses and roof sheeting. Within this image, the structural columns and beams can be observed, with further views of their connections available. An extremely important element that is shown within the footage is the bracing members that have been installed. As shown in red in Figures 27 and 28, several diagonal members have been constructed for the structural columns. The bracing systems vary depending on the column, but they serve a very important function to counteract the wind force that would be felt by the building. Again, connection arrangements for these braces can be observed, but specific sizing cannot.

Figure 27 - Brace Sets and Columns

Figure 28 - Brace Sets and Columns

Site 5

Description

Site 5 consisted of footage capturing of a recently constructed steel farm shed. With approximate dimensions of in length of 18m by a width of 6m. The structure consisted of cold-formed steel portal frames, with sheeting to 2 sides.

This site allowed for a view of what data can be captured for framing elements of a structure, with frame inspections being a vital stage for most structures.

Conditions

The flight was conducted during a sunny, low-wind day. The site area was well maintained, with little to no obstacles in place, allowing for simple piloting around and within the building.

Imagery Collected and Analysis

Data was collected during an approximately 10-minute flight. During this first flight, the members and the varying connections were observed, as outlined in the below stills taken from the flight.

The first 2 stills selected, noted as figures 29 and 30, outline the general layout of the shed. These stills alone can provide important information to an inspector.

Figure 29 - Northern End of Shed

Figure 30 - Southern End of Shed

The first item of note is the bracing. As highlighted in green, strap bracing has been added to the rooves of all bays, and wall bracing added to all external walls that have been cladded. This allows for rigidity to the structure and is a feature that would require assessment during a structural inspection.

A view can also be gained of the number of purlins and girts that have been installed. Roof purlins and wall girts are required to be spaced at certain distances, and thus, the drone has allowed for an assessment of how many have been installed, and in turn, an estimation of the spacing can be determined, based on the dimensions of the shed.

These figures allow for the assessment of the bridging placement to purlins and girts. Bridging is applied to the underside of purlins and girts to again provide additional restraint to the bottom flanges of the cold-formed sections, and take the form of top hat battens screwed to the members. Examples of this are shown in red.

Finally, flybraces can also be seen throughout the drone-captured footage. Flybraces are installed to create additional restraints to the portal members, namely the columns and rafters. Locations and several flybraces can be assessed with the help of the drone footage. Further assessment of the flybracing can be done with the aid of figures 31 and 32, in which the makeup of these elements can be analyzed. Flybraces are made up of a folded metal plate, with 2 screws at each end to the purlin and 4 screws to the bottom flange of the portal rafters.

Figure 31 also provides the added visualization of the bolts installed to laminate the back-to-back cold-formed CEE rafters, as would be a requirement of the construction.

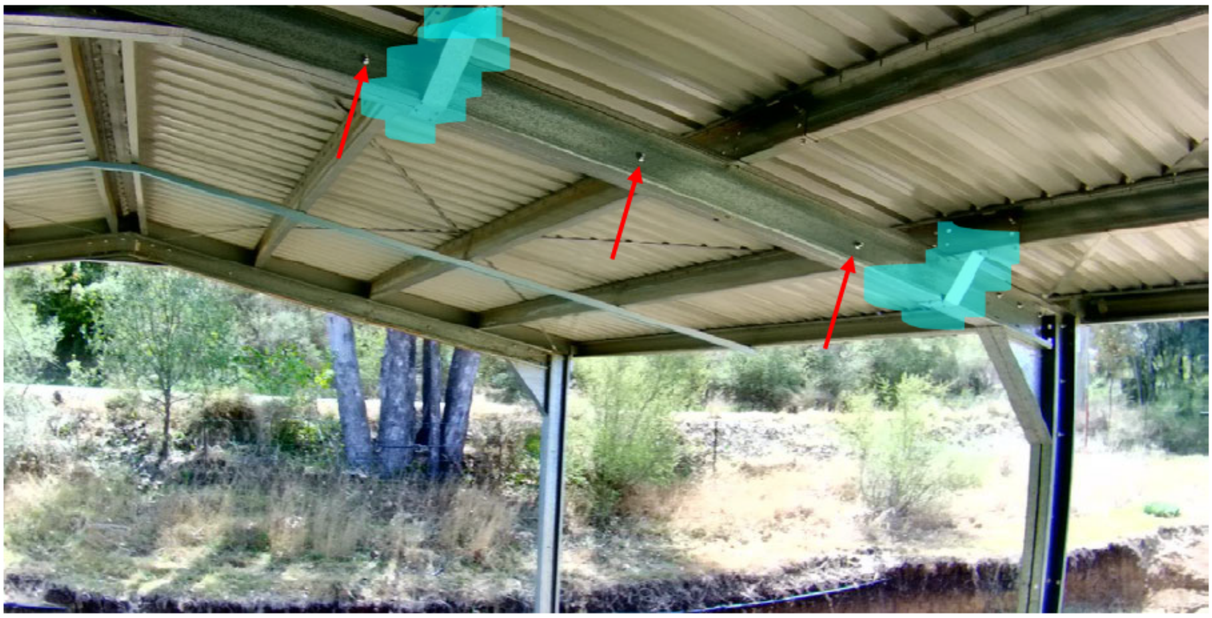

Figure 31 - Flybraces and Portal Rafters

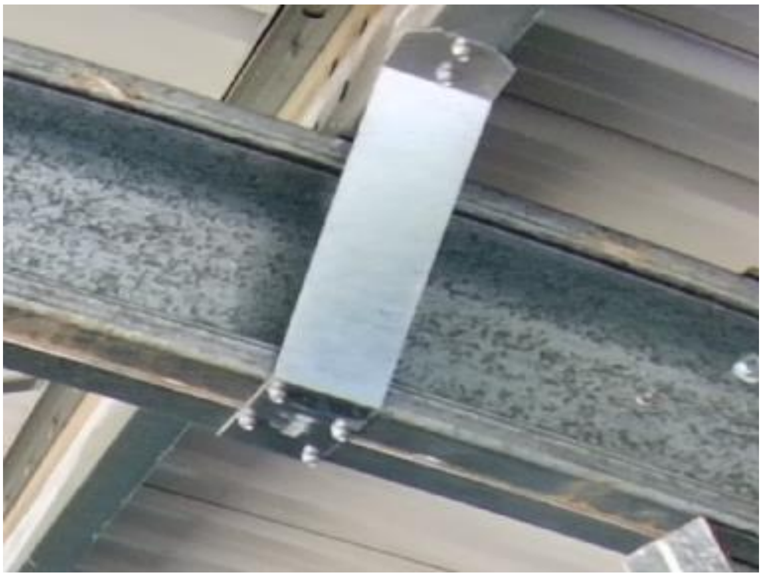

Figure 32 - Flybrace

Figure 33 allows for assessment to be made on the purlin lap and bolt arrangement. As is often a requirement of the purlin manufacturers and the designer, purlins, and girts are to have minimum lap over portal frames and requirements for bolts at connections. Figure 33 allows for an estimation of what lap has been provided and which bolts have been installed, the bolt to the bottom flange and a bolt to the top of the web.

Figure 33 - Purlin Lap and Bolt Arrangement

The next visually assessable aspect of the shed frame is the connections. Through careful piloting of the drone, footage could be captured of the major connections for the portal frame. As seen in Figure 34, the apex connection of the portal rafters is made up of folded metal plates between the back-to-back portal rafters, with six bolts to each rafter. Unfortunately, due to the nature of the connection and the drone's inability to determine small measurements, plate thicknesses, and bolt sizes could not be assessed, but the general arrangement can be easily viewed. Importantly, the number of bolts can be viewed and assessed as sufficient. Similar can be said for the rafter-to-column connection shown in Figure 35.

Figure 34 - Apex Connection

Figure 35 - Rafter to Column Connection

Survey Development

Being the secondary scope item of this research, the development of the appropriate professional survey was completed and finalized after the drone experimentation. It was determined that the best method to appropriately collect future professional opinions would be to break the survey into 2 sections, a questionnaire, followed by a Likert scale selection portion in which scenario suggestions are given a rating of strongly disagree, disagree, neither agree nor disagree, etc.

In order to develop this survey, a number of key question areas were developed to better build appropriate survey questions and scenarios. The key query areas developed for the survey are outlined below.

1- Remote construction projects and the concerns that they present.
2- Difficulties with the inspection process for remote construction projects.
3- Remote video inspections in construction.
4- Use of drones in construction.
5- Use of drones for structural inspections.
6- Openness to the use of drones for inspection.
7- Safety concerns/requirements.

The drone experimentation also allowed for further development of the survey questions. With first-hand experience of drone usage on a construction site, additional questions were developed for the survey. Items that the experimentation outlined for survey development include, but are not limited to:

1- Whether organizations would be willing to provide members with the required training to operate a drone on site.
2- Whether industry members have confidence in completing a structural inspection remotely using a drone.
3- What specific stages of construction would benefit from the use of drones for remote visual inspection?
4- Whether drones for progress monitoring could reduce delays in the remediation of defects.

With these aspects developed, the survey was built, using the required survey tool. Some example questions that were developed can be found below, with the full survey forming Appendix 7.

"Have you or your organization been required to complete engineering services on construction projects in remote areas of Australia? Note: remote also includes areas that may simply be large distances from your area of operations."

"During construction, were there difficulties in completing required inspections i.e. scheduling issues, organizing transport and accommodation etc? If so, please list."

"Did you complete any remote video inspections during the construction process?"

"How familiar are you with the use of UAVs (Unmanned Aerial Vehicles) in the construction industry?"

"Have you ever used UAVs for structural inspections in your projects? If yes, could you describe the experience?"

"Do you believe the use of drones for RVIs would be practical for structural inspections?"

"Would you be open to receiving training or resources to increase your understanding and usage of UAVs for inspections?"

Several example Likert scale scenarios can also be found below.

Drone footage would be effective in assessing foundation layouts and excavation depths remotely

❶ Choose one of the following answers
Please choose **only one** of the following:

- ◯ Strongly Disagree
- ◯ Disagree
- ◯ Neither Agree nor Disagree
- ◯ Agree
- ◯ Strongly Agree

Drones for construction progress monitoring could allow for defects to be remediated prior to a formal inspection

❶ Choose one of the following answers
Please choose **only one** of the following:

- ◯ Strongly Disagree
- ◯ Disagree
- ◯ Neither Agree nor Disagree
- ◯ Agree
- ◯ Strongly Agree

Drones for structural RVIs could improve efficiency of construction projects in remote locations

❶ Choose one of the following answers
Please choose **only one** of the following:

- ◯ Strongly Disagree
- ◯ Disagree
- ◯ Neither Agree nor Disagree
- ◯ Agree
- ◯ Strongly Agree

Drones for structural RVIs could provide the same confidence as in person inspection in remote locations

❶ Choose one of the following answers
Please choose **only one** of the following:

- ◯ Strongly Disagree
- ◯ Disagree
- ◯ Neither Agree nor Disagree
- ◯ Agree
- ◯ Strongly Agree

Drones on a construction site would cause additional safety concerns

❶ Choose one of the following answers
Please choose **only one** of the following:

- ◯ Strongly Disagree
- ◯ Disagree
- ◯ Neither Agree nor Disagree
- ◯ Agree
- ◯ Strongly Agree

With the survey questions developed, the next requirement is to complete the relevant ethics approval documents and application. This application formed the basis to ensure that the survey does not present any ethical concerns. The application required additional information to be provided based on items including conflict of interest, participant protection, benefits, risks, and data storage. Several separate documents were also created and attached to this application, including a survey information sheet and introduction email so the information within them could be reviewed and approved. All of the abovementioned items can be found in the appendices of this report.

Experimentation Discussion

With drone footage captured and analyzed, it can now be determined what information can be observed for the particular sites and their stage of construction. In order to do so, important aspects of the varying inspection types have been isolated with an outline of to what degree these aspects could be viewed in each site. These results can also be summarized in Table 8.

Excavation Condition

The excavation condition is an important factor to consider when inspecting slabs and foundations. The condition can relate to the overall layout of the excavation, the condition of the soil after excavation, formwork, and even the weatherproofing of the excavation.

As noted in Table 8 and throughout the results section of this report, sites 1,2, and 3 allowed for assessment of the excavation condition, with beam locations confirmed, areas of concern in terms of cave-in outline, establishing of membrane within the slab, and correct placement of formwork.

Sites 4, 5, and 6 are framed sites, no insight could be gained concerning excavation conditions.

Excavation Dimensions

Excavation dimensions are extremely important when completing inspections for foundations and slabs. Improper dimensions could have catastrophic repercussions on the structural stability of the project.

Site 1 provided particular insight into the effectiveness of the Zero-X drone's ability to capture the measured dimensions of the bored pier holes. Similarly, site 1 allowed for the viewing of areas of interest within the slab, with the footage being clear enough to determine where slab thickenings had been placed.

Using a similar method, assessment of the foundation depths, widths, and beam spacings for site 2 could also be assessed and recorded with the use of the drone. Slab depths could also be recorded from site 3 with the use of the Zero-X drone.

Sites 4, 5, and 6 were not applicable in recording excavation footage.

Reinforcement Placement

During foundation and slab inspections, ensuring proper placement of reinforcement is vital. In this instance, placing refers to several items within the slab or foundation systems. The items that require review include, but are not limited to;

1- Correct number of bars placed in the foundations.
2- The correct lap of reinforcement at joins, intersections, and corners.

3- Correct cover to the steel reinforcement.
4- Appropriate slab protection bars at re-entrant and wet area corners.
5- Starter bars to tie the foundations to the slab.
6- Additional reinforcement for slab thickenings etc.

As outlined within the drone imagery data analysis, sites 1, 2, and 3 all allowed for the abovementioned items to be viewed. Some contention can be made regarding the cover to steel being visible, but appropriate chairing of the steel could be viewed, so there is a basis on which confident assumptions can be made.

Reinforcement Size

One of the most important factors in slab and foundation inspections is reinforcement size, which must be closely assessed and analyzed. It was found that, due to the often minimal size of reinforcement bars and mesh, drone usage was not appropriate for confirming reinforcement sizing. Considering sites 1, 2, and 3, the footage collected was not clear enough to make accurate determinations of the size of reinforcement. Measuring the bar's sizes for the drone to then be able to see the measurement was a far too difficult and risky task, with the need to get extremely close to the drone to allow footage of bar sizes to be captured.

Reinforcement Spacing

Spacing of reinforcement is vital to ensure the strength of concrete structures is achieved. Similar to the methods used to determine reinforcement depth, reinforcement spacing could be measured during inspection using a UAV. Using the drone as an assistant, measurements of bar spacing could be achieved, with the measurement taken and shown to the camera for capture. In the sites selected though, spacings of reinforcement, such as ligs and starter bars, spacings were relatively large, being between 500-1000mm, thus reasonable assumptions could be made when observing the entire footprint. In scenarios where smaller spacings were used, measuring and estimation of the spacings may be a more difficult task, as will be outlined within the limitations section of this discussion.

Framing Placement

As indicated within the drone imagery data analysis, the placement of structural framing members could be assessed using the drone footage. Counts can be easily completed to determine that the number of members installed is correct and their locations are reasonably accurate. This applies to items such as, but not limited to, columns, rafters, braces, purlins, girts, and bridging. All of these items could be assessed for correct placement using the selected Zero-X drone. The condition of elements could also be viewed using the drone, as conditions like rust, timber splitting, or major damage could easily be viewed, depending on the extent, based on the experimentation at sites 4 and 5.

Framing Sizing

Unfortunately, measuring framing member sizes was not easily achievable through the use of the drone. Due to the small measurements required, safety would be the main factor in allowing for members to be measured and easily viewed by the camera. This is an important aspect of structural inspections, but current technology and comfortability with the selected drone did not allow for this to be assessed.

Framing Connection Arrangement

Connection arrangement is another very important aspect of structural frame inspections. Things to be assessed under the topic of framing arrangement include the number of bolts, their locations, plate installation, and connection condition. As can be shown from the footage at sites 4 and 5, this can be easily assessed with the use of the Zero-X drone, with clear images showing the number of bolts and screws in connections, and showing the correct location of connections. A clear view can also be gained of the overall condition of the connection.

Framing Connection Sizing

Similarly, with the sizing of members, it is particularly difficult to assess the sizes and dimensions of connections through the use of drone footage. The ability to fly close does allow for some estimations to be made, but accurately determining plate sizes and thicknesses, bolt sizes and spacings, and screw specifications was not possible, as the safety of those measuring these elements and presenting them to the drone could not be guaranteed at the current level of experimentation.

Defects

Within all the abovementioned components of structural inspections, the main concern that needs to be eradicated is defects. Defects can have several forms within a construction project and can range from minor to catastrophic. Though the sample size is small and not a significant number of defects were present, the reviewed sites create a good baseline for what defects can be detectable through the use of a drone for remote inspections.

As discussed within the results and analysis section of this report, sites 1, 2, and 3 did have some defects detected, though only minor. The footage captured from the selected drone was able to locate off-cuts within the slab area that required removal before any pouring. Missing reinforcement could also be detected upon close examination.

Though sites 4, 5, and 6 did not have any major defects identified during the flights, it is quite easy to imagine that they would be able to be located. The footage gathered at site 4 provides insight into the accuracy of footage that can be obtained from a timber-framed structure. As no specific defects were present, only assumptions can be made about what would be detectable from the footage if it were present. For a timber structure such as this one, timber condition is an important factor. As can be seen in the stills within the analysis section of this report, it is believed that should it be required, the drone footage would prove to be effective in denoting particular damage or poor condition to the members. It is suspected that defects such as timber splitting or warp would be detectable with the use of the drone. Closer inspection of members within the higher portions of the structure could also be observed, proving beneficial for structures in which standard ladders may not be high enough to reach all locations.

Another defect that may be present within a structure such as the timber frame farm shed at site 4 would be missing members. The evidence and footage provided by the flight at site 4 outlines that if there were to be members missing, they could be detected during the remote inspection, as all members. Counts could be completed on the number of trusses and webs, number of battens, columns, and even brace sets. Strap bracing could be detected during the inspection, and therefore any missing strap would be quite clear to the viewers completing the flight.

Similarly to the timber-framed structure observed at site 4, missing structural elements would be quite obvious in the site 5 and 6 structures. With these structures being more of a kit nature, missing elements are quite unlikely, but in the off chance that something was to be missed by the contractor, it is expected that the drone footage would have the capability to capture and flag the defect. Missing elements may even extend to missing bolts or plates, as the footage clearly shows that these items can be viewed and assessed.

Recommendations for Drone Use for Remote Construction Inspections

As outlined within Table 8 and the discussions above, experimentation with the use of drones for remote structural inspections has allowed for a comprehensive preliminary analysis of the appropriateness of their use, and as such, recommendations can be made on what construction stages can benefit from the use of UAVs.

Structural Element	Site 1	Site 2	Site 3	Site 4	Site 5
Excavation Condition	✓	✓	✓	N/a	N/a
Excavation Dimensions	✓	✓	✓	N/a	N/a
Reinforcement Placement	✓	✓	✓	N/a	N/a
Reinforcement Size	×	×	×	N/a	N/a
Reinforcement Spacing	✓	✓	✓	N/a	N/a
Framing Placement	N/a	N/a	N/a	✓	✓
Framing Sizes	N/a	N/a	N/a	×	×
Framing Connection Arrangement	N/a	N/a	N/a	✓	✓
Framing Connection Sizing	N/a	N/a	N/a	×	×
Defects	✓	✓	✓	✓	✓

Table 8 - Structural Inspection Aspects Viewable with Drone

Remote Slab and Foundation Inspections

As evident from the results and discussion within this report, experimentation with the use of drones for slabs and foundations was very beneficial. A significant amount of important information can be gained with the use of a drone flight during construction, with essentially all aspects measurable and assessable during a well-completed drone flight.

This can greatly benefit the construction sector in remote locations of Australia, as the need for engineers and inspectors to travel to site can be reduced through the use of regular pre-pour fly-over inspections.

It is not suggested that UAV-operated inspections should, or can, replace in-person inspections at the current stage of drone technology, with on-site visual inspection still providing the most effective manner in assessing slab and foundation construction, as well as being the most direct method for communicating requirements to complete construction. But, as is clear from the footage gauged through the completion of this report, the opportunity is there for drones to streamline the construction and inspection process.

To outline how this streamlining could be achieved, an example scenario has been created to outline how a possible foundation and slab construction could benefit from the use of drones for inspection.

Example scenario: A large-scale residential warehouse is being constructed in a remote area of Queensland. The warehouse is to be used as a packing and distribution facility for local agricultural produce. As this warehouse is going to be serving as a place of employment for a large number of workers, structural integrity is of major importance.

The first stage of the construction is the drilling of several bored pier foundations. Inspection of these piers is required to ensure the design depth has been reached. With a single, or even 2-man team, and drone flyover of the foundation footprint could be completed, with a live link of the footage being transmitted to the inspection team via Microsoft Teams or a similar program. This would allow for the inspecting team to be able to both view the footage live and provide instruction to the pilot on-site to observe areas of interest, for example, “Manoeuvre the drone to the North-East corner of the footprint. Once in the location, face the drone South and sweep the drone West to capture the layout of piers so that a count can be completed”. This is an added benefit that standard video diaries and pictures cannot provide, as it allows the inspector to be confident that they are seeing exactly what they want at a particular location. During the flight, instruction is provided for one of the members of the team to measure each bored pier’s depth and demonstrate the correct depth has been reached. Depending on the reinforcement required for the piers, the inspection of pier holes could be entirely completed via the drone remote inspection, with enough information available for the inspection team to provide approval to pour.

The next stages, being foundation beams and slab, may prove a little more difficult to fully complete remotely. Depending on the pouring sequence and design, similar methods to the above can be used to assess the placement of reinforcement for any foundation beams and slabs within the warehouse, but the sizing of reinforcement does become difficult to assess, as is evident from the completed experimentation. This inspection may still require an on-site visit to finalize and approve pouring, but regular flights during the construction phase would serve as a tool for early detection of defects. From start to finish, laying of reinforcement could take multiple days, and if regular flights are conducted to review the progress of the construction remotely, it would be easy for the inspection team to flag any items that need addressing before the final in-person inspection. This ability to rectify issues would be beneficial, as it increases the chance that the final in-person inspection can be completed quickly, with the construction crew having already been alerted to and able to rectify issues before the inspector or inspection teams’ arrival on site and reducing the need for rectification works and reinspection. This could drastically streamline the process and mean the inspectors could be off-site possibly within the same day, reducing any lost time on other projects that couldn’t be completed during the inspection period and allowing construction to continue as per schedule.

An added benefit that the drone remote inspection method provides is the ability to record the virtual inspection, removing the possibility of he said / she said arguments if disputes are to arise. Recorded inspection can also allow for re-evaluation and review if required at a later date.

As shown in the example scenario, for concrete inspections alone, drone remote inspection and progress monitoring has allowed for what would usually be 2-3 onsite inspections, to reduce to quite possibly a single final in-person review.

Remote Frame Inspections

As was evident during the experimentation, frame elements were more difficult to assess with the drone. Certain aspects could be viewed, but framed elements often have significantly smaller elements and features that need to be reviewed. This was found to be difficult to confidently complete with the drone. General layout and framing placement would certainly be viewable, but specifics on connections would not be easily confirmed through the use of the drone. Again, it is unlikely that drone remote inspections could replace the confidence gained through on-site inspections for framing, but the likelihood of benefits is present.

Using the same example scenario, with the large warehouse to be framed with large steel portal frames, wall girts, and purlins. Typically, these types of structures would have particular bays braced for wind racking. As was found during the site 4 flight, the framing placement could be easily viewed and assessed with the use of a drone. Portal frame locations could be identified, a count could be completed on the number of girts and purlins installed, bracing locations identified and even purlin and girt bridging could be confirmed.

Similarly, with the foundation aspect of the example scenario, it is expected that the details involved in framing inspections are too small to be easily assessed in full with the use of the drone, but similarly again, with the use of regular staged flights during construction, drone usage would greatly benefit progress management of a project to detect defects before final in-person inspection. The turnaround and efficiency of any final onsite inspection could be easily improved through the use of construction monitoring via drone, reducing any wait time on approval to proceed/finalize construction.

Conclusion

The major goal of this project was to determine if drones are a viable tool to allow for remote structural inspections, namely to allow for additional ease in construction in remote locations of Australia. The use of drones in the Australian construction industry is lacking compared to the rest of the world, and this study aimed to determine whether the advancement in technology is adequate for Australian construction scenarios.

Through the use of a Zero-X branded lightweight drone, experimentation has allowed for a clear view of what aspects of construction projects can be assessed through the use of a low to mid-budget drone.

The area deemed to most benefit from the use of UAV-completed inspections is the foundation and slab stages of a construction project. The experimentation provides valuable insight into the assessable items through the use of a budget drone, and the majority of inspectable aspects involved in foundation and slab construction could be identified with the use of the drone. These aspects being the excavation condition, dimensions, reinforcement placement, and reinforcement spacing. Though exact measurements may be difficult to assess, with the help of reasonable estimations and experience, these items could be analyzed. Sizing of smaller elements, namely reinforcement sizes was deemed too difficult to achieve with the current technology and skill levels.

Structural framing assessment was less successful, and it is believed that further research and technological advancement may be necessary to allow for drone inspections to be a viable alternative to in-person frame inspections, but this research has allowed for further insight into how effective drone inspection/project monitoring can benefit construction projects.

Additionally, it is quite clear from the results of the experimentation that drone-gathered footage and inspection is an excellent way for off-site personnel to complete progress management and outline possible areas of interest prior to formal inspections.

The secondary goal was to provide advancements and an introduction to future research through the development of the professional industry survey. Though the survey wasn't issued as a part of this report, the research involved in developing the survey provided valuable insight into the questions that will best highlight the opinions of those in the construction industry on the adoption of this technology. The seven query areas were developed to allow for the best level of responses to be achieved.

The survey's construction also provided valuable insight into the processes required for survey development. These processes will be extremely beneficial to future research if, for example, survey questions need to be revised and/or new ethical approvals need to be gained.

It is strongly believed that this research has allowed for further insight into the possibilities of drones currently being underused in the Australian construction industry and has allowed for extension into future research on the topic.

Limitations

During the course of the experimentation, there were several limitations and hurdles discovered for the use of the selected drone for data collection and retrieval, which could be detrimental to the effectiveness of UAVs for remote inspections.

Drone Selection

Though the drone used for the experimentation was deemed acceptable to record the required information, it did come with its limitations. The first limitation noted for this drone was that it cannot livestream footage to conference apps such as Microsoft Teams or Skype. This is detrimental to the drone's ability to complete such virtual remote inspections, but as the main focus of this research was based on footage accuracy, the limitation did not affect the experimentation. It does though rule out this model of drone for use to complete mandatory structural inspections remotely.

Although not a concern when completing this experiment, the selected drone does have a relatively short flight time of 28 minutes. All flights completed during experimentation were much shorter than this. Large-scale projects may require much longer flights in order to give inspectors the confidence to accept the methodology of drone complete inspections. This can be combated with additional batteries should longer flights be required, but if this is not possible, flight times for the selected drone should be confirmed as adequate before implementation.

Removal of tactile ability required for inspection

During the analysis of the footage, it was quite clear that one of the major limitations of RVIs in general was the inability to have tactile interaction with inspectable items. Being able to touch members and elements of a structure is a very important part of the process. This can relate to checking that bolts are correctly tightened, bracing is appropriately taut and reinforcement is appropriately supported and tied. Typical RVIs may be able to combat this by recording someone else completing these tasks, but member safety may become compromised if this approach is taken during drone-completed RVIs.

Inability to safely assess elements that require small measurements

Similarly to the point above regarding tactile inspection, drone RVIs also make it more difficult to assess members and elements that require small measurements, such as bolt and reinforcement sizes. Safely recording these measurements proved difficult, as it required getting quite close to the drone during its flight. There was also the opportunity to, due to the small size of measurements, easily compromise the value, as close inspection of the measurement taking could not be completed.

Future research may be able to combat these limitations through the use of further advancement in drone technology, particularly with drones that can be fitted with additional scanning software that may be able to provide accurate measurements of small structural elements.

Weather

As was discussed with the footage results and analysis, all but site 4 were visited on calm weather days. Site 4 gave valuable insight into how adverse high winds could be to the completion of a remote inspection using the drone. Winds did make flying somewhat more difficult, with the requirement to occasionally land the drone until wind gusts retreated. Clearly, with the size and power of the selected drone, wind speeds could result in inspections not being possible at a particular site. This is an aspect that would need to be considered for possible future implementation of this technology. All drone manufacturers have recommendations for maximum wind speeds in which operation should occur. These guidelines will need to be strictly followed if this technology is to be adopted.

Unfortunately, weather also played a part in the number of sites that could be visited throughout the duration of this research project. Additional sites were expected to be captured, but rain events resulted in the cancellation of the use of the drone. The current development in drone technology does not allow for operation during wet weather, and thus rainfall must be a factor to consider when performing inspection with the use of drones. Additionally, drone manufacturers do not recommend flights be performed during high temperatures and storage of batteries in high-temperature areas can result in defaults in the drone, so temperature can also be detrimental to drone performance and adoption.

Though this is seen as a limitation to the research experimentation, weather-related issues can also affect in-person inspection, with the cancellation of an in-person inspection likely proving more costly than rescheduling a drone-completed assessment.

File Sizes

An unexpected limitation that was discovered during the experimentation period was the large file sizes of the drone footage. When downloading the footage, it was found that some of the files were over 5 GB. This made downloading from the relevant drone app quite difficult and time-consuming. The large file size could become a concern for future organizations, as download limits may apply and sharing of the footage can be quite difficult with a large file size. Any efforts to reduce the sizes may result in poorer video quality. Organizations would need to factor this into their planning for file storage of drone-captured footage.

Flight Skill

The flyability of the selected Zero-X drone was quite simple when considering large, open-air sites, but during the frame inspection experimentation, it became quite obvious that a high level of skill was required to safely maneuver the drone in tights spaces, particularly between trusses and close to roofs and walls. To have high confidence in operator and bystander safety during remote inspection, it is expected that operators would need to ensure that appropriate flight training has been completed, as the damages that could be caused due to poor operation could be quite severe.

Future Research

With the limitations discovered through the experimentation period, several areas of future research were identified. They are noted below as follows;

1- Professional Survey – As was discussed previously, unfortunately, the constructed survey could not be issued to review industry professional opinions on the use of drones for remote inspection. This would be a valuable area to explore in the future.

2- Drone Selection – Future experimentation with more advanced drone models would further benefit the research into drones for remote inspections. A particular feature that would be beneficial would be a drone that is capable of sharing live footage with a professional streaming service, thus the effectiveness of live assessment could be further investigated. Drones with better camera technology and more advanced software could also be utilized, with the possibility of laser scanning technology being utilized. Finally, more advanced drones can allow for predetermined flight plans to be created and followed, which could likely improve the overall accuracy and ease of footage capture.

3- Additional Projects – Future research and experimentation could be completed into varying projects in the construction industry to further gauge the appropriateness of drone usage. A larger and more diverse sample group would further develop the research. Projects such as high rises, retaining walls, and residential framing projects could be analyzed to determine if drone footage is appropriate.

4- Safety Analysis – A further improvement that can be made to future research is to complete an in-depth analysis of the safety benefits that the use of drones for inspection may present. Workplace health and safety is a very important aspect of construction, and the use of drones could serve as an effective tool to improve the safety of inspecting agents. If drones are found to be accurate, the amount of high-risk maneuvering can be reduced, particularly work at heights.

5- Improved Analysis of Drone Accuracy – Further developments in the approach taken to assess the accuracy of drones may allow for improved outlining of drone accuracy for use in construction inspections. The analysis could use numerical data and statistics to better display the results a further improve the data analysis. This would likely mean a larger number of sites would need to be assessed to best represent the results numerically.

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Appendices

Appendix 1 (McAnulty and Baroudi 2010)

Table 1: Likert Scale Results for Human Resources Issues

	Human Resources Issues	(%) **SD**	**D**	**DK**	**A**	**SA**
1	Your company is currently experiencing difficulty attracting and retaining skilled or any other workers.	1.3	16.0	5.3	60.0	17.4
2	Skilled labour problems are more acute for projects in remote locations.	0.0	16.0	6.7	56.0	21.3
3	Given the current high level of construction activity, city based companies are constrained by labour shortages when vying for remote work.	0.0	14.6	12.0	66.7	6.7
4	Companies are in direct competition with the mining industry to attract and retain labour.	0.0	9.3	8.0	60.0	22.7
5	Firms prefer FIFO to permanently relocating staff.	1.3	24.0	21.3	46.7	6.7
6	There is a high level of acceptance to work in a remote location by employees who are offered FIFO compared to "permanent" relocation.	0.0	10.7	10.7	69.3	9.3
7	There is a higher level of employee turnover for companies who offer FIFO than those companies that relocate families on a "permanent" basis.	1.3	13.3	41.4	40.0	4.0
8	Companies prefer longer work cycles for FIFO employees.	1.3	14.7	12.0	64.0	8.0
9	Employee alcohol/drug use is higher when working in remote regions.	0.0	22.7	17.3	53.3	6.7
10	Working in remote locations has a negative impact on an employee's family life.	0.0	2.7	5.3	58.7	33.3

Table 2: Likert Scale Results for Production and Cost Management Issues

	Production and Cost Management Issues	(%) **SD**	**D**	**DK**	**A**	**SA**
1	The availability of materials and equipment has a considerable effect on productivity on remote area projects.	0.0	1.3	2.7	58.7	37.3
2	The skills of your workforce plays an important role in the productivity level in remote locations more so than in city locations.	0.0	21.3	2.7	54.7	21.3
3	Remote area climate does affect productivity and it is important to take this into account.	0.0	1.3	1.3	64.1	33.3
4	Alcohol abuse has a serious affect on productivity in remote locations.	0.0	13.3	8.0	44.0	34.7
5	The difficulty in procuring materials and equipment causes major problems for projects.	0.0	13.3	2.7	65.4	18.6
6	It is felt that procuring materials and equipment needed for projects is becoming more difficult.	0.0	17.3	5.3	66.7	10.7
7	Your strategy of material and equipment procurement differs between city and remote construction projects.	1.3	24.0	9.3	57.4	8.0
8	Delivery times for materials and equipment is a problem on remote projects.	0.0	12.0	5.3	64.0	18.7
9	An engineer should supervise and report on vital material and equipment deliveries on remote construction projects.	2.7	20.0	4.0	49.3	24.0
10	Your company is continually updating our cost knowledge base when tendering for remote projects.	0.0	4.0	9.3	70.7	16.0
11	Pricing for work in remote locations is more difficult than city locations.	0.0	20.0	2.7	62.7	14.6

Table 3: Likert Scale Results for Infrastructure and Communications Issues

	Infrastructure and Communications Issues	(%) **SD**	**D**	**DK**	**A**	**SA**
1	The lack of certain infrastructure affects your decision to work in remote locations.	1.3	24.0	2.7	68.0	4.0
2	There is planning for future infrastructure developments and they will be sufficient.	1.3	25.3	45.4	28.0	0.0
3	The government should be solely responsible for infrastructure.	8.0	65.3	8.0	14.7	4.0
4	Communication is a significant problem when working in remote locations.	1.3	33.3	2.7	52.0	10.7
5	Your company invests in the latest technology to minimize communication issues when working in remote locations.	0.0	13.3	6.7	66.7	13.3

(Storey 2001, McAnulty and Baroudi 2010)

Appendix 2 (Bowers, Lo et al. 2018)

1 Demographic characteristics of the 1124 workers who participated in the survey

Sex		Travel arrangements to work	
Men	1051 (93.5%)	Fly in/fly out	1105 (98.3%)
Women	73 (6.5%)	Drive in/drive out	12 (1.1%)
Age (years)		Daily commute (< 1 hour)	7 (0.6%)
16–24	114 (10.1%)	Roster swing	
25–34	415 (36.9%)	1 week on/1 week off	186 (16.5%)
35–44	295 (26.2%)	2 weeks on/1 week off	519 (46.2%)
45–54	223 (19.8%)	4 weeks on/1 week off	374 (33.3%)
≥ 55	77 (6.9%)	Other	45 (4.0%)
Mining sector		Time with this company	
Construction	434 (38.7%)	< 6 months	184 (16.4%)
Underground	475 (42.3%)	6–12 months	181 (16.1%)
Open pit	215 (19.1%)	1–2 years	257 (22.9%)
Relationship status		2–5 years	344 (30.6%)
Single	298 (26.5%)	> 5 years	158 (14.1%)
Married/de facto	734 (65.3%)	Time at site/project	
Separated	52 (4.6%)	< 6 months	261 (23.2%)
Widowed	40 (3.6%)	6–12 months	285 (25.4%)
Dependents under 18		1–2 years	247 (22.0%)
None	634 (56.4%)	2–5 years	288 (25.6%)
One	182 (16.2%)	> 5 years	43 (3.8%)
Two or more	308 (27.4%)	Location of rest and recreation	
Highest level of education		Perth	533 (47.4%)
Did not complete high school	396 (35.2%)	Adelaide	118 (10.5%)
High school or equivalent	218 (19.4%)	Other Australian cities	149 (13.3%)
Diploma/trade certificate	412 (36.7%)	Regional Western Australia	123 (10.9%)
University	98 (8.7%)	Regional South Australia	44 (3.9%)
Mining location		Other regional Australia	118 (10.5%)
Western Australia	649 (57.8%)	Overseas	39 (3.5%)
South Australia	475 (42.3%)		

2 Psychological distress levels (K10) and self-rated mental health for 1124 survey participants and the general Australian population

	Survey participants	Australian population[26]*
Psychological distress levels (K10 scores)		
Low (10–15)	448 (39.9%)	70.1%
Moderate (16–21)	365 (32.5%)	18.4%
High (22–29)	240 (21.4%)	7.4%
Very high (30–50)	71 (6.3%)	3.4%
Self-reported mental health		
Poor	45 (4.0%)	4.4%
Fair	197 (17.5%)	10.4%
Good	446 (39.7%)	28.9%
Very good	302 (26.9%)	36.5%
Excellent	114 (10.1%)	19.8%
Missing data	20 (1.8%)	—

K10 = Kessler Psychological Distress Scale questionnaire. * Weighted to adjust for the predominantly male sample (93.5%). ◆

3 Level of stress associated with work, lifestyle and family factors

	Not stressed	Slightly stressed	Very stressed
Work-related stressors (1061 responses)			
Travelling to and from work	502 (47.3%)	386 (36.4%)	173 (16.3%)
Accommodation	657 (61.9%)	303 (28.6%)	101 (9.6%)
Work colleagues	472 (44.5%)	439 (41.4%)	150 (14.2%)
Immediate supervisors	494 (46.6%)	363 (34.2%)	204 (19.2%)
Senior management	439 (41.4%)	341 (32.1%)	281 (26.5%)
Job tasks	452 (42.6%)	424 (40.0%)	185 (17.4%)
Shift length	530 (50.0%)	312 (29.4%)	219 (20.7%)
Shift roster	403 (38.0%)	318 (30.0%)	340 (32.0%)
Availability of help if needed	653 (61.5%)	252 (23.8%)	156 (14.7%)
Stigma attached to mental health problems	626 (59.0%)	279 (26.3%)	156 (14.7%)
Physical environment	542 (51.1%)	346 (32.6%)	173 (16.3%)
Lifestyle-related stressors (1098 responses)			
Living in remote circumstances	437 (39.8%)	387 (35.2%)	274 (24.9%)
Social isolation	437 (39.8%)	351 (32.0%)	310 (28.2%)
Lack of social participation	511 (46.5%)	326 (29.7%)	261 (23.8%)
Inability to practise religion	975 (88.8%)	77 (7.0%)	46 (4.2%)
Lack of general facilities	650 (59.2%)	294 (26.8%)	154 (14.0%)
Lack of access to telecommunications	625 (56.9%)	249 (22.7%)	224 (20.4%)
Lack of public transport	917 (83.5%)	93 (8.5%)	88 (8.0%)
Family-related stressors (869 responses)			
Missing special events (eg, birthdays)	118 (13.6%)	264 (30.4%)	487 (56.1%)
Relationship with partner	278 (32.0%)	245 (28.2%)	346 (39.8%)
Relationship with children	399 (45.9%)	196 (22.6%)	274 (31.5%)
Relationship with parents	461 (53.0%)	224 (25.8%)	184 (21.2%)
Financial situation	328 (37.7%)	252 (29.0%)	289 (33.3%)

4 Demographic characteristics associated with psychological distress in 1124 survey participants (multinomial univariate regression)

		Moderate K10 score		High/very high K10 score	
Demographic	*P*	OR (95% CI)	*P*	OR (95% CI)	*P*
Mining sector	0.001				
Construction		0.8 (0.5–1.1)	0.12	0.4 (0.3–0.6)	< 0.001
Underground		1.0 (0.7–1.4)	0.87	0.9 (0.6–1.3)	0.46
Open pit		1		1	
Age (years)	0.001				
16–24		1.9 (1.0–3.5)	0.06	2.6 (1.2–5.6)	0.018
25–34		1.8 (1.0–3.0)	0.035	3.2 (1.6–6.2)	0.001
35–44		1.1 (0.6–1.9)	0.68	2.6 (1.3–5.0)	0.006
45–54		0.9 (0.5–1.6)	0.82	1.8 (0.9–3.7)	0.09
≥ 55		1		1	
Sex	0.26				
Relationship status	0.014				
Divorced/widowed		1.0 (0.5–2.0)	0.90	0.7 (0.3–1.6)	0.40
Separated		1.5 (0.7–3.4)	0.32	3.7 (1.8–7.6)	0.001
Married/de facto		1.1 (0.8–1.5)	0.60	1.1 (0.8–1.6)	0.47
Single		1		1	
Number of dependents under 18	0.10				
Education	0.78				
Occupation	0.07				
Roster swing	< 0.001				
1 week on/1 week off		1.4 (0.9–2.1)	0.12	1.6 (1.0–2.5)	0.039
2 weeks on/1 week off		1.4 (1.0–1.9)	0.05	2.4 (1.7–3.4)	< 0.001
4 weeks on/1 week off		1		1	
Other		0.5 (0.2–1.0)	0.06	1.0 (0.5–2.0)	0.91
Duration of previous job	0.20				
Time at current company	0.32				
Time in current job	0.11				

CI = confidence interval; K10 = Kessler Psychological Distress Scale questionnaire; OR = odds ratio. ◆

5 Demographic characteristics associated with psychological distress in 1124 survey participants (multinomial multivariate regression)

		Moderate K10 score		High/very high K10 score	
	P	OR (95% CI)	*P*	OR (95% CI)	*P*
Work-related factors					
Immediate supervisors	0.024				
Not stressed		1		1	
Slightly stressed		1.2 (0.8–1.7)	0.46	1.6 (1.0–2.7)	0.048
Stressed		1.3 (0.7–2.5)	0.38	2.0 (1.0–4.3)	0.06
Very/extremely stressed		0.9 (0.4–2.4)	0.89	4.3 (1.6–11.3)	0.003
Job tasks	0.034				
Not stressed		1		1	
Slightly stressed		1.3 (0.9–2.0)	0.14	1.7 (1.0–2.7)	0.039
Stressed		1.2 (0.6–2.3)	0.57	2.2 (1.1–4.4)	0.031
Very/extremely stressed		2.9 (0.9–9.8)	0.08	6.2 (1.8–21.2)	0.004
Shift length	0.042				
Not stressed		1		1	
Slightly stressed		1.1 (0.8–1.7)	0.52	1.5 (0.9–2.5)	0.12
Stressed		1.0 (0.5–1.9)	0.98	2.4 (1.2–5.1)	0.017
Very/extremely stressed		0.5 (0.2–1.4)	0.19	0.5 (0.2–1.6)	0.25
Shift roster	0.05				
Not stressed		1		1	
Slightly stressed		1.5 (0.9–2.3)	0.10	0.9 (0.5–1.6)	0.67
Stressed		2.2 (1.2–3.9)	0.010	0.9 (0.4–1.8)	0.76
Very/extremely stressed		2.6 (1.2–5.8)	0.017	1.5 (0.6–3.8)	0.39
Stigma attached to mental health problems	< 0.001				
Not stressed		1		1	
Slightly stressed		2.1 (1.4–3.1)	< 0.001	3.6 (2.2–5.9)	< 0.001
Stressed		2.7 (1.1–6.3)	0.023	19.6 (8.3–46.6)	< 0.001
Very/extremely stressed		1.9 (0.5–6.5)	0.33	23.5 (7.5–73.2)	< 0.001
Physical environment	0.06				
Lifestyle-related factors					
Remote living circumstances	< 0.001				
Not stressed		1		1	
Slightly stressed		2.2 (1.5–3.1)	< 0.001	1.5 (1.0–2.3)	0.06
Stressed		3.6 (2.1–6.1)	< 0.001	4.1 (2.4–7.3)	< 0.001
Very/extremely stressed		1.3 (0.5–3.2)	0.62	3.7 (1.6–8.6)	0.002
Inability to pursue religious/spiritual practices	0.018				
Not stressed		1		1	
Slightly stressed		1.1 (0.6–2.3)	0.72	2.7 (1.4–5.5)	0.004
Stressed		0.8 (0.2–2.8)	0.68	2.4 (0.8–7.8)	0.14
Very/extremely stressed		2.7 (0.5–15.4)	0.27	3.1 (0.6–17.2)	0.19
Lack of access to telecommunications (eg, social media)	0.10				
Family-related factors					
Relationship with partner	< 0.001				
Not stressed		1		1	
Slightly stressed		1.5 (0.9–2.4)	0.14	1.2 (0.6–2.1)	0.61
Stressed		1.6 (0.9–2.8)	0.08	1.6 (0.8–3.0)	0.17
Very/extremely stressed		3.4 (1.5–7.8)	0.003	8.2 (3.5–19.3)	< 0.001
Financial situation	< 0.001				
Not stressed		1		1	
Slightly stressed		1.5 (0.9–2.3)	0.08	1.3 (0.8–2.3)	0.28
Stressed		2.9 (1.7–5.2)	< 0.001	4.6 (2.5–8.5)	< 0.001
Very/extremely stressed		3.3 (1.5–7.1)	0.002	6.0 (2.7–13.1)	< 0.001
Lack of access to telecommunications (eg, family contact)	0.07				

CI = confidence interval; K10 = Kessler Psychological Distress Scale questionnaire; OR = odds ratio. * Comparison group: low distress level. ♦

Appendix 3 – Risk Management Plan

4931	RISK DESCRIPTION	STATUS	TREND	CURRENT	RESIDUAL
	ENP4111 - Analysis of the accuracy of drone footage in structural engineering construction	Live		Medium	Low

RISK OWNER	RISK IDENTIFIED ON	LAST REVIEWED ON	NEXT SCHEDULED REVIEW
Maxwell Hall	06/06/2024	04/09/2024	04/03/2025

RISK FACTOR(S)	EXISTING CONTROL(S)	CURRENT	PROPOSED CONTROL(S)	TREATMENT OWNER	DUE DATE	RESIDUAL
Potential for high temperatures during data collection	Control: Long Sleeved Shirt, long pants, sun protection ____________ Control: Hydration breaks as required	Very Low	No Control:			Very Low
Trip and fall hazards associated with being on a construction site. Falling down excavation Tripping on steel reinforcement	Control: Previous experience on construction sites and current possession of white card and site safety training. ____________ Control: Wearing proper PPE and footwear to both prevent trip and fall risk and to reduce potential injury	Low	Assessment of ground conditions and obstacles prior to experimentation. If possible, remove obstacles that may cause hazard.Vigilance on site to ensure care taken. Site workplace health and safety training to be completed if required on site. Flag items on site that are to be avoided or monitored, such as excavation and exposed steel		06/06/2024	Very Low
			Further practice and training for use of drone for confidence in flight ability.		06/06/2024	
			During operation of the drone, ensure pilot location is in a stable area with an appropriate clear radius around the user, thus to ensure that while observing the drone, trip or other distractions do not occur.			
The drone may collide with an obstacle during the flight due to a lack of proper control caused by poor visibility, and the wreckage may fall over to cause injuries or casualties. The drone may stop operating at mid-flight and cause itself a hazard that may lead to human injury or collide with private or	Control: Appropiate PPE and protection used during use of drone ____________ Control: Regular equipment maintenance, calibration check. Drones are implementing proximity sensors that prevent collisions. They also designed	Medium	Ensure that drone is used within safe distance from self and others during flight, as per drone regulations and guidelines. Ensure safe distances maintained to external objects. Complete visual assessment on site to determine if any collision hazards. If found, perform assessment and ensure clearance to object maintained.		06/06/2024	Low

public property features such as buildings or pet or other animals.	to withstand harsh environmental conditions and reduce the likelihood of malfunctions or failures that could result in accidents or damage. ——— Control: Pilots must comply with CASA rules, regulations and licensing; including the 12 recreational drone rules; takeoff and landing will take place away from any inhabited areas; and a public exclusion zone will be established where possible. ——— Control: Operating in appropriate weather conditions. ——— Control: Ensuring full battery during operation of drone ——— Control: Condition of drone is well maintained and operational. ——— Control: Connectivity between the aircraft and the controller is always maintained.		Further practice and training for use of drone for confidence in flight ability		06/06/2024	
			Implement additional safety features including testing equipment before using them in the field.			

Appendix 4 – Survey Ethics Application

Ethics ETH2024-0488 (HREC): Mr Maxwell Hall (Student) (Low risk)

Academic/Researcher	Mr Maxwell Hall (Student) Dr Andy Nguyen
Project	Analysis of the Appropriateness of Using UAV for Structural Inspections of Remote Construction Projects
Division	Academic Division
Faculty/Department	Academic Affairs

Ethics application

Overview

Application initiated by:
Mr Maxwell Hall (Student)

Ethical Considerations

Are you working with animals or humans?
Humans, human data or human tissue

Do you have a current approval from another Ethics Committee to conduct this project?
No

Project title
Analysis of the Appropriateness of Using UAV for Structural Inspections of Remote Construction Projects

Project summary
This research will analyse the use of drones to complete structural inspections of construction works in remote areas. This analysis will be completed in part with an industry professional survey to get general perceptions and opinions on the use of drones for inspection. The overall objective is to determine what aspects of construction inspection can benefit from the use of drones and also determine how industry professional may adopt this technology. This is to complete an honours research project.

Host department
School of Engineering

Project duration
1 year

Is your research being conducted within Australia?
Yes

Select all that apply:
All Australian States and Territories

Does this project relate to, and/or extend on a previously approved project.
No

Is this project funded?
No

Investigators

Principal Investigator

□
Dr Andy Nguyen
UniSQ ID
[redacted]

Person type
Staff

Organisational area
School of Engineering

Other affiliations

Field of Research (FoR)
400505. Construction materials; 400508. Infrastructure engineering and asset management; 400510. Structural engineering ;

Co-investigator (UniSQ Staff)

Co-investigator (UniSQ Student)

□□
Mr Maxwell Hall (Student)
UniSQ Student ID
[redacted]

Type of student
UGRD Student

Program
BENH - Bachelor of Engineering (Honours)

Organisational area
School of Engineering

Field of Research (FoR)

Does the project involve co-investigators from another university or organisation?
No

Conflict of interest

Does the Principal Investigator or any other members of the research team have an actual, perceived, or potential personal or financial Conflict of Interest (CoI) in relation to the project?
No

Do any of the Co-Investigators or External Investigators have an actual, perceived, or potential personal or financial Conflict of Interest (CoI) in relation to the project?
No

Outline the Conflict of Interest (CoI) and advise on how it will be managed.

Qualifications and Experience

Principal Investigator - qualifications and experience

Principal Investigator
Dr Andy Nguyen

Qualifications relevant to project
Bachelor of Engineering (Civil), Master of Engineering (Structural), PhD (in Structural Health Monitoring field)

Experience relevant to project
20 year research experience (including 10 years post-PhD) in Structural Health Monitoring field, which this honours project is part of

Co-Investigator - qualifications and experience

Co-Investigator
Mr Maxwell Hall (Student)

Qualifications relevant to project
BENH - Bachelor of Engineering (Honours) - UGRD Student

Experience relevant to project
10 years relevant industry experience

Operational Items

Does this project include:
not applicable

The following options were available for selection:

- *Genetically Modified Organism (GMO)*
- *biological material (non-GMO), e.g. work with toxins, mutagens, teratogens, carcinogens etc.*
- *biological material native to Australia that was (or will be) collected in Queensland for commercial purposes*
- *radioactive substances and/or ionising radiation? (e.g. DXA, X-ray)*

Does this project include:
not applicable

The following options were available for selection:

- *the export, supply, publishing, or brokering of controlled goods, software, or technology*
- *an arrangement with a foreign government or foreign university that does not have institutional autonomy not applicable*
- *not applicable*

Analysis of the Appropriateness of Using UAV for Structural Inspections of Remote Construction Projects

First copy:
UniSQ OneDrive

Second Copy:
SharePoint

Third copy:
Secure local desktop

How will you protect your data from loss and unauthorised access?
3 separate copies saved Passwords applied

Who needs access to your data?
Project supervisor and myself

What is the required retention period for your data?
5 years for research data not resulting in a patent

At the completion of the project, where will you keep your research data in order to meet the required retention period
Secure local desktop and sharepoint/google drive

Additional Information

Do you have a UniSQ Risk Management Plan relating to the activities being undertaken in this project?
No

Ethical considerations - Human

Participant involvement

In what way are human participants involved in your project:

Direct recruitment and/or observation of human participants
Yes

How many groups of participants will you be recruiting and/or observing for this research project?
1

Existing data sets and/or archival data
No

Existing Human biospecimens
No

Genomic research (includes full scope of genetic research)
No

Clinical trials
No

Aims and significance

Background
This research will analyse the use of drones to complete structural inspections of construction works in remote areas. This analysis will be completed in part with an industry professional survey to get general perceptions and opinions on the use of drones for inspection. This will be coupled with further drone experimentation to assess the accuracy of drone footage.

Aims
The overall objective is to determine what aspects of construction inspection can benefit from the use of drones and also to determine how industry professional may feel towards adopting this technology, thus determining how remote inspection can be improved. The main research questions is essentially 'Can drones improve inspection procedures for construction in remote areas?'

Justification and significance
The benefit of this project would be that it may lead to vast improvements within the construction and engineering sectors within remote Australian locations, making remote construction projects more effecient for all parties involved.

Has your project been peer reviewed?
No

Type of Research

Do you have adequate resources available for this research project?
Yes

What type of research are you undertaking in this project?
action
quantitative
qualitative
case study

The following options were available for selection:

- *medical (can be interventional, observational or lab-based)*
- *clinical*
- *biomedical*
- *epidemiological*
- *clinical trial*
- *use of drug or therapeutic device*
- *mental health*
- *public health*
- *dental*
- *action*
- *quantitative*
- *qualitative*
- *case study*
- *social science*
- *oral history/biographical*
- *other*

Identifying participant group/s

Will there be direct recruitment or use of existing data and/or tissue from any of the following participant groups?
n/a (none of the participant groups above are target groups for this project)

The following options were available for selection:

- *women who are pregnant, the human foetus, or human foetal tissue*
- *children or young people under the age of 18 years*
- *people with a cognitive impairment, an intellectual disability, or a mental illness*
- *people considered to be a forensic or involuntary patient*
- *people with impaired capacity for communication*
- *prisoners or people on parole*
- *people highly dependent on medical care, including a person who is unconscious*
- *military personnel*
- *military veterans*

- *people who would not usually be considered vulnerable but would be considered vulnerable in the context of this project*
- *Aboriginal and/or Torres Strait Islander peoples*
- *hospital patients*
- *people residing outside Australia*
- *people who would be considered to use English as a Second Language (ESL)*
- *people who would be considered to use English as a Foreign Language (EFL)*
- *n/a (none of the participant groups above are target groups for this project)*

Benefits and Risks

Benefits

The potential benefits of the project are:

- gains in knowledge, insight and understanding
Yes

Explain how this benefit will be achieved as a result of this research being conducted
It will benefit industry professionals to know if drones as an advancement in technology could streamline and increase efficiency for structural inspection procedures.

- improved social welfare
No

- improved individual wellbeing
No

- Other
No

Risks

The following types of risks (either short or long term) may occur due to participation in this project:

- physical (including injury, illness, pain)
No

- psychological (including feelings of worthlessness, distress, guilt, anger or fear related, for example, to disclosure of sensitive or embarrassing information)
No

- social (including damage to social networks or relationships with others; discrimination in access to benefits, services, employment or insurance; social stigmatisation)

No

- devaluation of personal worth (including being humiliated, manipulated or in other ways treated disrespectfully or unjustly)
No

- economic (including the imposition of direct or indirect costs on participants)
No

- legal (including discovery and prosecution of criminal conduct)
No

- inconvenience (including taking the time to fill in the survey, participate in an interview etc)
Yes

Expand on this risk and its relevance to your project. Outline arrangements you will put in place to minimise this risk
Time to complete the online survey.

It is expected that the completion of the survey should take approximately 30 minues.

Participants will be informed of the time required to complete prior to commiting to the starting of the survey

Due to this survey only forming a small part of the honours project, risk is very low in terms of the survey result.

- discomfort (including minor side-effects of medication, the discomforts related to measuring blood pressure, and anxiety induced by an interview)
No

- Other
No

Would any of the risk factors that you have identified above be potentially considered to be more than low risk factors?
No

Project Team

What is the level of risk for the project team?
Low

Outline the strategies that you have in place to address the level of risk to the project team?
Due to this survey only forming a small part of the honours project, risk is very low in terms of the survey result.

Primary investigator has extensive knowledge of subject matter.

Primary investigator has extensive industry experience.

Co-investigator has extensive industry experience.

Data collection and access

Data Collection

Data Collection considerations
none of the above apply to this project

The following options were available for selection:

- *collection of data in a rural and remote setting*
- *travelling overseas to collect data*
- *physiological or psychological testing of participants*
- *none of the above apply to this project*

Data Access

Will any research data be made available or shared via open access, restricted access, mediated access or as metadata only?
Yes

Provide further details about the data that will be made available/shared, and via what method.
Restricted access to the data through the thesis submission will be made available. Data will be used to provide analysis of expert opinion. All data will be made available to assessors if requested. Data will be made available to other researchers, but the data will be remain confidential.

Will any individual or organisation external to UniSQ (i.e. a third party) have access to the research data during the project?
No

Other Considerations

UniSQ Course projects

Are you a course leader intending to undertake this project as a UniSQ Course project?
No

Upload any relevant or supporting documentation

Course information

Permissions to access participants

Are you required to obtain permission to access your group/s of participants?

No

Does your project include the recruitment of UniSQ staff or students?
No

Evidence of approval/endorsement

Monitoring your project

What will you do in cases where unexpected events or emergencies occur as a result of participation in this project?
Highly unlikely that emergency will occur as a result of the participation in the survey questionnaire.

If emergency is to occur, appropriate emergency services will be contacted, advise from supervisor will be sought, contact shall be made with UniSQ to notify and action will be taken as advised

Communication of findings

Publishing your findings

Method of Communication
research thesis

If providing individual test results to each participant, what arrangements will be in place to deal with participant's distress in the case of adverse results?

The following options were available for selection:

- *research thesis*
- *journal article*
- *book or book chapter conference presentation (not published in a proceedings)*
- *open access dataset*
- *published report to organisation or community group*
- *private report to organisation or community group*
- *report to all participants*
- *executive summary of results*
- *individual test results to each participant (eg from physiological or psychological testing)*
- *media (eg article in "The Conversation")*
- *creative output*
- *other*

Will the participants and/or other interested stakeholders be able to access these findings and/or request a copy of the summary of results?
Yes

Provide further information with regards to accessibility of these results

Restricted access to the data through the thesis submission will be made available. Data will be used to provide analysis of expert opinion. All data will be made available to assessors if requested. Data will be made available to other researchers, but the data will be remain confidential.

Particpants may recieve access to a summary of the results if requested.

When disseminating your findings, will participants be
non-identifiable (i.e. no individual or organisation can be identified)

The following options were available for selection:

- *non-identifiable*
- *re-identifiable*
- *identifiable or presented in a manner which may allow some participants to be identified.*
- *other*

Participant - Group 1

Group 1 name
Engineer/Certifier/Construction Employee Survey

How many individual participants are expected to be recruited in this group?
10

Describe the participants in this group:
Engineers and building certifiers with experience in structural inspections of building projects.

Construction workers

Where will this group of participants be recruited from?
Publicly available websites and Industry publications

Will any potential participants in this group be under 18?
No

Is there a pre-existing relationship between the participants and anyone involved in recruiting and/or collecting data from this group
No

Do these participants have any cultural needs?
No

Recruitment of Participants

How will you recruit participants?
Email

Indicate how you will obtain the contact details of these participants

from participants themselves
from a public domain source

If from private or third party, or other source, provide further information around the source

Provide details of who will be inviting participants and further explain the method/s they will use, as identified above.
The co-investigator

Participants will be contacted via email to inform and request for participation. This will be the only method of contact, unless contact is made from participants.

Will you be offering payment or any other incentives to this group of participants?
No

Recruitment information

Data Collection

Method of collection
survey/questionnaire

Provide further details for this data collection method
A questionnaire will be provided to the participants via email. Email will include the link for the survey that has been built using the USQ survey tool. Surveys will be conducted anonymously online with the participants submitting their surveys showing consent to participate.

Are particular qualifications required to use this method?
No

Will you be recording participants?
No

Documents you have referred to for this group which may include: Survey instrument, question list, protocol for administering a substance

Data Collection documentation specific to this group

Participation

What are you asking participants in this group to do or what is to be done to them?
1- Participants will be emailed requesting they take part in the survey. Email will include an introduction, information sheets and link to the survey, outlining all the requirements of the survey and the information required.

2- Participants will then choose to take part in the survey or not.

3- Once the survey is begun, participants can exit any time if they wish.

3- Consent to use the survey data will come with the submission of the survey. This will be made clear throughout the email and information provided in step 1.

4- Once participant responses are received, they will be analysed.

5- Analysed responses will be formalised within the research report, a copy of which can be provided for participant review if requested.

How much time are you asking of participants in this group and when will this time be required?
30 minutes at their leasure

Specifically, where will this data be collected?
Data will be collected via internet response to survey. Co-investigator located in Warwick QLD. Surveys will be conducted online through use of the USQ survey tool

Does the research involve measures or procedures that are diagnostic or indicative of any medical or clinical condition, or any other situation of concern?
No

Will a Participant Information Sheet be provided to the participants?
Yes

It is strongly recommended that you use the UniSQ template which has all required fields including purpose, risks, benefits and referral services.

Participant Information Sheet

If you are not using a Participant Information Sheet (or similar), how will this project be communicated to participants?

Will participants be referred to support services?
No

Consent

Are these participants able to consent for themselves?
Yes

Will participants be fully informed about the true nature of the research?
Yes

Consent type

How will you obtain consent from this group of participants?
Implied consent

Participant Consent Type - Group 1

Implied consent

How you will gauge that consent to participate has been implied by this group of participants?

Return of Questionnaire

This is outlined in both the introduction email and information sheet. It is also within the starting page of the survey

Additional Documentation

Do you need to upload any additional documentation?

Yes

Any additional supporting documentation for this application

How do these additional documents support your project?

Survey Questions attached.

Appendix 5 – Survey Information Sheet

University of Southern Queensland

University of Southern Queensland
Participant Information Sheet
Questionnaire

UniSQ HREC Approval number: ETH2024-0488

Project Title

Analysis of the Appropriateness of Using UAV for Structural Inspections of Remote Construction Projects

Research team contact details

Student Investigator details

Mr Maxwell Hall
Email: [redacted]umail.usq.edu.au
Mobile: [redacted]

Principal Supervisor details

Prof Andy Nguyen
Email: [redacted]
Telephone: [redacted]

Description

This project is being undertaken as part of a Bachelor of Engineering Honours final year research project through the University of Southern Queensland.

The purpose of this project is to analyse the use of drones to complete structural inspections of construction works in remote areas. This analysis will be completed through site experimentation with the use of drones in conjunction with an industry professional survey to get general perceptions and opinions on the use of drones for inspection. The overall objective is to determine what aspects of construction inspection can benefit from the use of drones and also determine how industry professional may adopt this technology.

Participation

Your participation will involve completion of an online questionnaire that will take approximately 30 minutes of your time.

Questions will include: How familiar are you with the use of UAVs (Unmanned Aerial Vehicles) in the construction industry? Have you ever used UAVs for structural inspections in your projects? If yes, could you describe the experience?

The survey will also include questions with responses based on a liker scale i.e. Strongly Disagree, Disagree, No Opinion, Agree, Strongly Agree. Questions within this section will include: Drones for structural RVIs could improve efficiency of construction projects in remote locations, Drones for structural RVIs could reduce travel requirements for projects in remote locations

Your participation in this project is entirely voluntary. If you do not wish to take part, you are not obliged to. If you decide to take part and later change your mind, you are free to withdraw from the project at any stage. You will be unable to withdraw data collected about yourself after you have participated in the questionnaire.

Your decision whether you take part, do not take part, or take part and then withdraw, will in no way impact your current or future relationship with the University of Southern Queensland.

Expected benefits

It is expected that this project will directly benefit you in that it may lead to vast improvements within the construction and engineering sectors within remote Australian locations, making remote construction projects more efficient for all parties involved. It may also serve as a benefit to the structural inspection requirements as a whole.

Risks

In participating in the questionnaire, there are no anticipated risks beyond normal day-to-day living.

Privacy and confidentiality

All comments and responses are confidential unless required by law.

The names of individual persons are not required in any of the responses.

Restricted access to the data through the thesis submission will be made available. Data will be used to provide analysis of expert opinion. All data will be made available to assessors if requested. Data will be made available to other researchers, but the data will remain confidential with members non-identifiable.

Participants may receive access to a summary of the results if requested.

Any data collected as a part of this project will be stored securely, as per University of Southern Queensland's Research Data and Primary Materials Management Procedure.

Consent to participate

Clicking on the 'Submit' button at the conclusion of the questionnaire is accepted as an indication of your consent to participate in this project.

Questions

Please refer to the Research team contact details at the top of the form to have any questions answered or to request further information about this project.

Concerns or complaints

If you have any concerns or complaints about the ethical conduct of the project, you may contact the University of Southern Queensland, Manager of Research Integrity and Ethics on +61 7 4687 5703 or email researchintegrity@unisq.edu.au. The Manager of Research Integrity and Ethics is not connected with the research project and can address your concern in an unbiased manner.

Thank you for taking the time to help with this research project. Please keep this document for your information.

Appendix 6 – Survey Introduction Email

Introduction Email

Hello,

My name is Maxwell and I am writing to you today to request your participation in a brief survey.

I am a student completing a bachelor's of Engineering through the University of Southern Queensland and am currently completing my final year research project. My selected research project is titled "Analysis of the Appropriateness of Using UAV for Structural Inspections of Remote Construction Projects". As the title suggests, the purpose of this project is to analyse the use of drones to complete structural inspections of construction works in remote areas. This analysis will be completed through site experimentation with the use of drones in conjunction with an industry professional survey to get general perceptions and opinions on the use of drones for inspection. The overall objective is to determine what aspects of construction inspection can benefit from the use of drones and also determine how industry professionals may adopt this technology.

I would like to utilise your professional experience in the construction industry to determine what perception and opinions are to the use of drones for inspections in remote areas. Your responses to this survey will help to evaluate the overall opinions of engineering and construction professionals in regard to drones as tools for inspections.

The survey is will be brief and will only take about 30 minutes to complete. Please click the link below to go to the survey website.

Survey link:

Your participation in the survey is completely voluntary and all of your responses will be kept confidential. No personally identifiable information will be associated with your responses to any reports of these data. Further details can be found in the attached information sheet. Should you have any comments or questions, please feel free to contact me at [redacted] or on [redacted]

Thank you very much for your time and cooperation.

Sincerely,

Maxwell Hall, [redacted]

Appendix 7 – Professional Survey

Appropriateness of Using Drones for Structural Inspections of Remote Construction Projects

UniSQ HREC Approval number: ETH2024-0488

Description

This project is being undertaken as part of a Bachelor of Engineering Honours final year research project through the University of Southern Queensland.

The purpose of this project is to analyse the use of drones to complete structural inspections of construction works in remote areas. This analysis will be completed through site experimentation with the use of drones in conjunction with an industry professional survey to get general perceptions and opinions on the use of drones for inspection. The overall objective is to determine what aspects of construction inspection can benefit from the use of drones and also determine how industry professional may adopt this technology.

Participation

Your participation will involve completion of an online questionnaire that will take approximately 30 minutes of your time.

Questions will include: How familiar are you with the use of UAVs (Unmanned Aerial Vehicles) in the construction industry? Have you ever used UAVs for structural inspections in your projects? If yes, could you describe the experience?

The survey will also include questions with responses based on a likert scale i.e. Strongly Disagree, Disagree, No Opinion, Agree, Strongly Agree. Questions within this section will include: Drones for structural RVIs (Remote Video Inspections) could improve efficiency of construction projects in remote locations, Drones for structural RVIs could reduce travel requirements for projects in remote locations

Your participation in this project is entirely voluntary. If you do not wish to take part, you are not obliged to. If you decide to take part and later change your mind, you are free to withdraw from the project at any stage.

You may also request that any data collected about you be withdrawn and confidentially destroyed.

If you do wish to withdraw from this project or withdraw data collected about yourself, please contact the Research Team (contact details at the top of this form).

Your decision whether you take part, do not take part, or take part and then withdraw, will in no way impact your current or future relationship with the University of Southern Queensland.

Expected benefits

It is expected that this project will directly benefit you in that it may lead to vast improvements within the construction and engineering sectors within remote Australian locations, making remote construction projects more efficient for all parties involved. It may also serve as a benefit to the structural inspection requirements as a whole.

Risks

In participating in the questionnaire, there are no anticipated risks beyond normal day-to-day living.

Privacy and confidentiality

All comments and responses are confidential unless required by law.

The names of individual persons are not required in any of the responses.

Restricted access to the data through the thesis submission will be made available. Data will be used to provide analysis of expert opinion. All data will be made available to assessors if requested. Data will be made available to other researchers, but the data will remain confidential with members non-identifiable.

Participants may receive access to a summary of the results if requested.

Any data collected as a part of this project will be stored securely, as per University of Southern Queensland's Research Data and Primary Materials Management Procedure.

Consent to participate

Clicking on the 'Submit' button at the conclusion of the questionnaire is accepted as an indication of your consent to participate in this project.

Questions

Please refer to the Research team contact details at the top of the form to have any questions answered or to request further information about this project.

Concerns or complaints

If you have any concerns or complaints about the ethical conduct of the project, you may contact the University of Southern Queensland, Manager of Research Integrity and Ethics on [redacted] or email [redacted] The Manager of Research Integrity and Ethics is not connected with the research project and can address your concern in an unbiased manner.

Research team contact details

Student Investigator details

Mr Maxwell Hall

Email: [redacted]

Telephone:

Mobile: [redacted]

Principal Supervisor details

Prof Andy Nguyen

Email: [redacted]

Telephone: [redacted]

Mobile:

There are 43 questions in this survey.

Questionnaire

What construction department do you represent? *

❶ Choose one of the following answers

Please choose **only one** of the following:

- ◯ Engineer
- ◯ Certifier
- ◯ Builder/Contractor
- ◯ Architect/Building Designer
- ◯ Other [ ]

Have you or your organisation been required to complete engineering services on construction projects in remote areas of Australia? Note: remote also includes areas that may simply be large distances from your area of operations.

Only answer this question if the following conditions are met:
Answer was 'Engineer' at question '1 [Q0]' (What construction department do you represent?)

Please write your answer here:

Have you or your organisation been required to provide approval on construction projects in remote areas of Australia? Note: remote also includes areas that may simply be large distances from your area of operations.

Only answer this question if the following conditions are met:
Answer was 'Certifier' at question '1 [Q0]' (What construction department do you represent?)

Please write your answer here:

Has your organisation been required to complete construction projects in remote areas of Australia? Note: remote also includes areas that may simply be large distances from your area of operations.

Only answer this question if the following conditions are met:
Answer was 'Builder/Contractor' at question '1 [Q0]' (What construction department do you represent?)

Please write your answer here:

Have you in your time in the construction industry, been involved in construction projects in remote areas of Australia? Note: remote also includes areas that may simply be large distances from your area of operations.

Only answer this question if the following conditions are met:
Answer was 'Architect/Building Designer' *or* 'Other' at question '1 [Q0]' (What construction department do you represent?)

Please write your answer here:

If yes, did you encounter any issues during the process? Please list below

Please write your answer here:

What process was taken to complete structural inspections during the construction period? Please outline below.

Please write your answer here:

During construction, were there difficulties in completing required inspections i.e. scheduling issues, organising transport and accommodation etc? If so, please list.

Please write your answer here:

Did you complete any remote video inspections during the construction process?

Please write your answer here:

Are remote video inspections a common requirement generally within your organization?

Please write your answer here:

How familiar are you with the use of UAVs (Unmanned Aerial Vehicles) in the construction industry?

Please write your answer here:

Have you ever used UAVs for structural inspections in your projects? If yes, could you describe the experience?

Please write your answer here:

If you haven’t used UAVs for inspections, what are the main reasons?

Please write your answer here:

Do you believe the use of drones for RVIs would be practical for structural inspections?

Please write your answer here:

What do you see as the main benefits of using UAVs for structural inspections?

Please write your answer here:

What challenges or concerns do you foresee in using UAVs for structural inspections?

Please write your answer here:

What construction stages do you believe could be completed efficiently with the use of unmanned aerial vehicle footage?

Please write your answer here:

Are you aware of any regulations or guidelines related to the use of UAVs for structural inspections in your region?

Please write your answer here:

How do you feel about the current regulations? Are they sufficient or do they need improvements?

Please write your answer here:

What is your opinion on making the use of UAVs mandatory for certain types of structural inspections?

Please write your answer here:

What factors should be considered in deciding whether the use of UAVs should be mandatory?

Please write your answer here:

Would you have confidence in completing an inspection remotely using a drone?

Please write your answer here:

Would your organisation require training in order to utilise UAVs for structural inspections?

Please write your answer here:

Would you be open to receiving training or resources to increase your understanding and usage of UAVs for inspections?

Please write your answer here:

What is your overall perception of using UAVs for structural inspections?

Please write your answer here:

How do you see the role of UAVs in the construction industry evolving in the future?

Please write your answer here:

Likert Scale

Drone footage would be effective in assessing foundation layouts and excavation depths remotely

❗ Choose one of the following answers

Please choose **only one** of the following:

- ◯ Strongly Disagree
- ◯ Disagree
- ◯ Neither Agree nor Disagree
- ◯ Agree
- ◯ Strongly Agree

Drone footage would be effective in assessing foundation reinforcement remotely

❗ Choose one of the following answers

Please choose **only one** of the following:

- ◯ Strongly Disagree
- ◯ Disagree
- ◯ Neither Agree nor Disagree
- ◯ Agree
- ◯ Strongly Agree

Drone footage would be effective in assessing slab reinforcement remotely

❶ Choose one of the following answers
Please choose **only one** of the following:

- ◯ Strongly Disagree
- ◯ Disagree
- ◯ Neither Agree nor Disagree
- ◯ Agree
- ◯ Strongly Agree

Drone footage would be effective in assessing structural framing elements remotely

❶ Choose one of the following answers
Please choose **only one** of the following:

- ◯ Strongly Disagree
- ◯ Disagree
- ◯ Neither Agree nor Disagree
- ◯ Agree
- ◯ Strongly Agree

Drones for construction progress monitoring would be an effective way to detects remotely

❶ Choose one of the following answers
Please choose **only one** of the following:

- ◯ Strongly Disagree
- ◯ Disagree
- ◯ Neither Agree nor Disagree
- ◯ Agree
- ◯ Strongly Agree

Drones for construction progress monitoring could allow for defects to be remediated prior to a formal inspection

❶ Choose one of the following answers
Please choose **only one** of the following:

- ◯ Strongly Disagree
- ◯ Disagree
- ◯ Neither Agree nor Disagree
- ◯ Agree
- ◯ Strongly Agree

Drones for structural RVIs could improve efficiency of construction projects in remote locations

❗ Choose one of the following answers
Please choose **only one** of the following:

- ◯ Strongly Disagree
- ◯ Disagree
- ◯ Neither Agree nor Disagree
- ◯ Agree
- ◯ Strongly Agree

Drones for structural RVIs could reduce travel requirements for projects in remote locations

❗ Choose one of the following answers
Please choose **only one** of the following:

- ◯ Strongly Disagree
- ◯ Disagree
- ◯ Neither Agree nor Disagree
- ◯ Agree
- ◯ Strongly Agree

Drones for structural RVIs could improve safety of construction projects in remote locations

❶ Choose one of the following answers
Please choose **only one** of the following:

- ◯ Strongly Disagree
- ◯ Disagree
- ◯ Neither Agree nor Disagree
- ◯ Agree
- ◯ Strongly Agree

Drones for structural RVIs could provide the same confidence as in person inspection in remote locations

❶ Choose one of the following answers
Please choose **only one** of the following:

- ◯ Strongly Disagree
- ◯ Disagree
- ◯ Neither Agree nor Disagree
- ◯ Agree
- ◯ Strongly Agree

Drones for structural RVIs could replace in person inspections

❗ Choose one of the following answers

Please choose **only one** of the following:

- ◯ Strongly Disagree
- ◯ Disagree
- ◯ Neither Agree nor Disagree
- ◯ Agree
- ◯ Strongly Agree

Live feed and recording of drone footage during structural site stages would benefit your organisation and its projects

❗ Choose one of the following answers

Please choose **only one** of the following:

- ◯ Strongly Disagree
- ◯ Disagree
- ◯ Neither Agree nor Disagree
- ◯ Agree
- ◯ Strongly Agree

Live feed and recording of drone footage during structural site stages would allow for better record keeping of remote site conditions

❗ Choose one of the following answers
Please choose **only one** of the following:

- ◯ Strongly Disagree
- ◯ Disagree
- ◯ Neither Agree nor Disagree
- ◯ Agree
- ◯ Strongly Agree

Drones for structural RVIs would require extensive training

❗ Choose one of the following answers
Please choose **only one** of the following:

- ◯ Strongly Disagree
- ◯ Disagree
- ◯ Neither Agree nor Disagree
- ◯ Agree
- ◯ Strongly Agree

The remote sites you have worked on have adequate mobile service to complete a live RVI

❗ Choose one of the following answers
Please choose **only one** of the following:

- ◯ Strongly Disagree
- ◯ Disagree
- ◯ Neither Agree nor Disagree
- ◯ Agree
- ◯ Strongly Agree

Drones on a construction site would cause additional safety concerns

❗ Choose one of the following answers
Please choose **only one** of the following:

- ◯ Strongly Disagree
- ◯ Disagree
- ◯ Neither Agree nor Disagree
- ◯ Agree
- ◯ Strongly Agree

The benefits of Drones for RVI out way the cons

Choose one of the following answers
Please choose **only one** of the following:

- Strongly Disagree
- Disagree
- Neither Agree nor Disagree
- Agree
- Strongly Agree

Thank you for taking the time to help with this research project. Please keep this document for your information.

Submit your survey.
Thank you for completing this survey.