Remote Construction Inspection Utilization Across the State of Ohio

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ABSTRACT. The emergence of the COVID-19 pandemic has forced organizational shifts and policy changes across the world. The construction industry has not been immune to these changes and has altered traditional construction practices to adapt to the pandemic. Specifically, the construction inspection process has seen dramatic changes in the acceptance of remote forms of inspection in lieu of in-person inspection processes. This study evaluates the status of remote construction inspections across Ohio. Using surveys distributed to each authority having jurisdiction (AHJ), it assesses the current utilization, application, and attitudes toward remote construction inspections. The study found that approximately 40% of responding AHJs in Ohio reported using remote visual inspections (RVIs) for construction inspections, most of which were adopted in response to the pandemic. Additionally, 88% of the AHJs that have adopted RVIs do not use a standard set of RVI guidelines, although over 90% reported standard guidelines would be beneficial. The findings also revealed that 97% of respondents who used RVIs indicated some level of satisfaction with the method (31% were somewhat satisfied, 44% were satisfied, and 22% were very satisfied). To provide adequate support to building inspectors, ensure the safety of structures, and promote the evolution of technology in the industry, it is imperative for researchers and policymakers to understand AHJ positions on RVI implementation across the state.

KEYWORDS. Remote visual inspections (RVI), COVID-19, photogrammetry, authority having jurisdiction (AHJ), Ohio

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INTRODUCTION

Building inspections represent one of the core processes necessary for successful completion of a construction project. The main goal of building inspections is to ensure that different building requirements are met by ensuring compliance with the minimum standards set forth in the building codes (Listokin and Hattis 2005; Hess et al. 2007). Proper inspection of built facilities is therefore necessary to ensure safety and a high standard of living for the residents (Municipality of Cumberland 2013). Traditionally, building inspections have been conducted in person, with inspectors physically visiting the construction sites to inspect building elements. Even though this practice has been around for many years, and is widely accepted by municipalities, it has many shortcomings. Several studies have shown that, in some instances, this practice can be risky, expensive, and time-consuming (Freimuth and König 2018; Seo et al. 2018; Wells and Lovelace 2018; Asadzadeh et al. 2022). In addition, the construction industry is experiencing a shortage of building inspectors, which compounds the problem (ICC 2014).

The outbreak of COVID-19 in 2020 compelled several industries to investigate methods of performing work that limit human physical interaction in response to social distancing protocols. The construction industry was not immune to these measures. Building inspectors were compelled to explore alternatives that would not only be effective and reliable but would also ensure their safety and that of the construction workers. Remote Visual Inspection (RVI) methods emerged as a practical alternative to conventional in-person inspections. RVIs are potentially more affordable, safer, faster, and more convenient. These modern inspection methods can also make the profession more appealing by offering flexibility, allowing inspectors to work from home or other remote locations.

Although there are specific situations where RVIs have been established as a better alternative to the conventional in-person site inspection method

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from safety, cost, and scheduling perspectives, there are still questions about their overall benefits and limitations. For any emerging method or technology, it is important to investigate the perceptions of potential users who, in this case, include contractors, owners, design professionals, and building inspectors. To date, no research has investigated the perceptions of building inspectors toward the use of RVIs on commercial and residential construction in Ohio. The preponderance of RVI research focuses on identifying damage and deterioration of pre-existing civil infrastructure, including bridges, railroads, pipelines, dams, and solar panels, etc., most of which is done using drones (Aghaei et al. 2015; Otero et al. 2015; Freimuth and König 2018; Seo et al. 2018; Wells and Lovelace 2018; Asadzadeh et al. 2022).

LITERATURE REVIEW

During construction, several inspections are conducted at different phases of the building process. The main goal of building inspections is to ensure that different building requirements are met by ensuring compliance with design specifications and standards set forth in the building codes and contract documents (Listokin and Hattis 2005; Hess et al. 2007). Building inspection services help keep the public healthy and safe by making sure that buildings are designed and built in accordance with current building standards and laws (Municipality of Cumberland 2013). The identification of defects through inspections and the management of those defects is crucial to guaranteeing construction quality and safety (Dong et al. 2009).

Compliance requirements for building inspections typically involve regular inspections of the building's systems and components, including structural, electrical, plumbing, and mechanical systems. Building officials may also check for compliance with accessibility requirements, fire protection systems, and other safety measures. The frequency of inspections may vary depending on the type and use of the building, the requirements set by the local authority, and the complexity of the project.

Remote Visual Inspections

RVIs are conducted using various visual technologies, such as video conferencing, drones, and mobile apps, which allow inspectors to view and assess buildings from a remote location (Zandy 2020). Since their inception, RVI technologies have continued to evolve, incorporating features such as digital image capture and transmission, as well as automation and robotics. Modern RVI systems use a combination of imaging technologies, such as high-definition cameras, thermal imaging, and 3D laser scanning, to provide detailed visual information about the condition of equipment and infrastructure. Advances in wireless communication and data analysis have also made it possible to remotely control inspection equipment and analyze inspection data in real time, enabling more efficient and effective inspections.

Today, RVI is used in a wide variety of industries to help ensure the safety, reliability, and efficiency of equipment and infrastructure. For example, RVI is used in aerospace to inspect the interior of jet engines, in automotive manufacturing to inspect engine components, in oil and gas to inspect pipelines and storage tanks, and in power generation to inspect turbines and boilers. The development of RVI technology has made it possible to inspect and maintain equipment and infrastructure in a safe, efficient, and cost-effective manner, reducing downtime and ensuring the reliability of critical systems.

Current RVI Practices

RVIs rely on photography, videography, and photogrammetry to capture information that is then communicated to an inspector in a remote location. Images and videos recorded for inspection can provide the building inspector with information in a variety of ways. For instance, there are photogrammetry techniques that can be used to produce 3D construction models for inspection. The use of multi-image stitching techniques in photogrammetry allows for the creation of precise and high-resolution 3D models (Maas and Kersten 1997). This is done by capturing successive images that overlap by 80% to 90%. The camera is placed at reference locations, and then photos are taken at these points to acquire images that overlap. The parallax (apparent displacement) produced by overlaying the images is analyzed by image-processing algorithms, and a virtual 3D model is developed.

The COVID-19 pandemic forced many industries to adapt to remote work to avoid the spread of the virus. The construction industry was no exception,

and remote inspections became a viable option since they supported social distancing and reduced the risk of exposure to the virus. It was observed that various major cities including Seattle, New York City, and Pittsburgh adopted RVIs successfully (City of Pittsburgh 2020; City of Seattle 2020; New York City Department of Buildings 2020).

Video conferencing is one of the most commonly used technologies for remote building inspections. It allows inspectors to view the building in real time and communicate with the property owner, building contractor, or other parties who may be present on the project site. The City of Santa Ana in California is an example of a jurisdiction that has adopted the use of video conferencing for building inspections, including established guidelines that are available on their official webpage (City of Santa Ana n.d.).

Drones are another technology used in remote building inspections. They can provide high-quality aerial footage of the building, allowing inspectors to identify potential issues such as roof damage or cracks in the building's façade. In a study conducted by Alzarrad et al. (2022), drones were used to inspect the roofs of 2 houses in Hurricane, West Virginia. The drones were able to capture high-quality images of the roofs, allowing the inspectors to identify several defects, including damaged shingles and blocked gutters. Drones were also used to inspect a water tower in Kansas. The inspection was conducted by a team of engineers who used the drone to capture images of the tower from different angles. The images were stitched together to create a 3D model of the tower, allowing the engineers to identify several defects, including cracks in the concrete and rusted bolts.

Mobile apps are also increasingly being used for remote building inspections. They allow property owners to capture images and videos of the building using their smartphones, which can then be shared with the inspector for assessment. As noted by Einizinab et al. 2023, smartphones are increasingly utilized in virtual building inspections, enabling real-time image capture and facilitating remote collaboration among inspection teams.

Other methodologies exist, with more becoming available continuously. 3D laser-scanning and photogrammetry products such as OpenSpace®, Matterport®, FARO® Scanners, and Multivista® offer competitive RVI options. All these products can be used to submit visual data to AHJs for inspection and documentation purposes. Some of these methods are affordable, while others, such as laser scanning, are expected to become more affordable with widespread adoption and use. In addition, usability is a key benefit of these offerings, eliminating the main barrier generally associated with embracing new technology (Sepasgozar et al. 2016; Mihić et al. 2023).

Literature on RVIs

The first example of published literature about RVIs can be debated. However, substantial early RVI research (Garwin 1972; Pope et al. 1972) grew out of military projects, as well as exploration of civil uses. Early examples of civil uses included the National Aeronautics and Space Administration's (NASA) development of unmanned aerial vehicles (UAVs) (Aderhold et al. 1976) and the remote inspection of underwater pipelines by various fields (Scholley et al. 1975; Vadus 1976; Rechmitzer et al. 1986). It appears that in the 1970s and 1980s, researchers started to produce extensive examples of remote applications that overlapped slightly with construction. The 1970s saw 3 military services successfully demonstrate useful applications for remotely piloted vehicles (James 1972; Aderhold et al. 1976). In addition, NASA developed tangible applications for remote pilot vehicles in parallel with multiple military branches. While the exact moment when these research goals spilled over into modern RVI research may be uncertain, what is not debatable is that the initial research was launched from a military and space perspective and has seen subsequent expansion in the private sector as costs have reduced and technology has improved.

Construction-specific applications of remote inspections emerged later than many of the early remote sensing studies. One of the earliest references appears in Aderhold et al. (1976) which explored potential civilian uses for UAVs. The study identified more than 35 civil applications for remotely piloted vehicles, including the use of UAVs for pipeline patrols to detect and report leaks, identify nearby hazards, or monitor adjacent construction activity (Aderhold et al. 1976). Since the 1970s, civil use of remote inspections has expanded, and more construction-specific inspections appear to start populating the literature around 2015. An outlier published in 2003 is an earlier example of researchers highlighting the need for remote

inspections in infrastructure, predating the main body of literature in the mid 2010s (Ballado et al. 2003). Most studies focused on civil inspections using UAV methodologies (Hallermann and Morgenthal 2014; Henriques and Roque 2015; Khan et al. 2015; Otero et al. 2015; Yang et al. 2015; Gillins et al. 2016; Hernandez et al. 2016; Tatum and Liu 2017; Jordan et al. 2018). Another theme of this period is safety-specific inspections using UAVs (Irizarry et al. 2012; Costa et al. 2016; De Melo et al. 2017; Howard et al. 2018).

More recently, scholars have not only continued to expand the above themes (Outay et al. 2020; Perry et al. 2020; Feroz and Dabous 2021) but have started to summarize the impacts of remote inspections and user perceptions, as well as project future trajectories (Nawaz et al. 2019; Jeelani and Gheisari 2021; Rachmawati and Kim 2022). For example, a recent study tested residential contractors' perceptions and called for more remote inspection opportunities with a hybrid method (Morse et al. 2022). Another study evaluated risk metrics with inspections during the pandemic, with findings supporting the need for more online tools and applications (Tekin 2022). Furthermore, the International Code Council (ICC) produced a study in April of 2020 questioning code departments' status of inspections. The results showed 65% of jurisdictions reported that some or all employees conducting inspections and plan reviews were working remotely. However, 61% of the jurisdictions reported not having the capability to perform remote inspections (ICC 2020). Best practices for remote inspections have been issued by various jurisdictions, along with the ICC itself. Jurisdictions were also performing remote inspections prior to the pandemic; Los Angeles, Las Vegas, and Miami (Ohio), were using remote inspections to reduce travel times, among other benefits (Colker 2021).

Perception of Industry Professionals on the Use of RVIs

The City of Seattle (2020) reported that it had performed 22% of its inspections between April and August 2020 using RVIs. The city anticipated that its use would expand further and noted that RVIs offered the benefit of successful inspections during the pandemic. Remote inspections enabled the city to increase its inspection capacity without employing additional personnel. Other cities, including Milwaukee, Pittsburgh, Austin, New York City, San Antonio, Los Angeles, and Santa Rosa, have used remote building inspections successfully. Particularly, the City of Pittsburgh found remote inspection to be highly effective, with over 90% of their inspections being carried out remotely (City of Pittsburgh 2020).

Video conferencing (such as FaceTime®) and photographs were the popular media for carrying out these remote inspections. These cities found that remote building inspections increased inspection capacity (more inspections in a day), reduced exposure to COVID-19, improved inspection efficiency, maintained high quality, reduced costs, reduced travel time, reduced vehicle emissions, and increased satisfaction from residents (City of Austin 2020, City of Los Angeles 2020; City of Milwaukee 2020; City of Pittsburgh 2020; City of San Antonio 2020; City of Santa Rosa 2020; New York City Department of Buildings 2020).

A study conducted by the International Code Council (ICC) found that remote inspections can be used for a wide range of building types and stages of construction. The study also found that remote inspections can save time and reduce costs while also maintaining a high level of quality (ICC 2020).

The National Association of Home Builders (NAHB) also found remote inspections to be a valuable tool for home builders. Their study was consistent with that of the ICC and the municipalities. They found that remote inspections can help builders save time and reduce costs while also improving safety by reducing the number of in-person interactions required (NAHB 2020).

Hubbard and Hubbard (2020) investigated bridge inspectors' perceptions of the use of drones for remote inspections. Most bridge inspectors (83%) said that using a drone's video feed may be a useful tool for conducting inspections. According to the research, 62% of bridge inspectors thought UAS could be used for pre-inspection, 60% thought it could be used for post-inspection, and 57% thought it could be used for the actual inspections.

Duque et al. (2018) also investigated the perspectives of State Departments of Transportation (DOTs) on the use of drones for infrastructure inspections, particularly bridge inspections. Nineteen states responded to the survey that was distributed online to 50 DOTs. They found that only one state, Alaska, had used a specially made

drone to inspect bridges. Six other states (Florida, Idaho, Iowa, Kentucky, New York, and Wisconsin) planned to use drones for bridge inspection soon, while the rest did not. The consensus among all survey participants was that drone-shot photos and videos are the best sources of data for identifying bridge damage. The DOTs noted that regulations, poor lighting, and lost GPS signals are just a few of the challenges involved with the use of the technology.

Morse et al. (2022) investigated homebuilders' and contractors' perceptions of the use of remote visual inspections on residential and commercial projects in California. Although homebuilders believe that RVIs save time and money, they also believe that they are less accurate than conventional inspections. Of the 5 contractors interviewed, 2 had employed remote building inspection pre-COVID-19. However, the pandemic was influential on the decision of the other 3 to adopt RVIs.

Previous literature is rooted in history and provides a breadth of topics across disciplines; however, clear gaps exist in the literature. Research evaluating the effectiveness of inspections conducted within the structure is largely limited. While the contractor perspective on the use of RVIs is a topic that has been briefly explored by researchers, there is no study focusing on the perceptions of building inspectors or code officials. The current study attempts to bridge that gap by investigating the perceptions of Ohio building inspectors regarding the use of remote visual inspections. The research field of construction-specific inspections is in its infancy and this paper serves to contribute to this body of knowledge.

METHODOLOGY

The current study aims to explore the perceptions of Ohio building inspectors toward remote building inspections using a questionnaire survey. According to Groves et al. 2009, surveys are an effective method of obtaining a current snapshot of a specific group, profession, organization, or population. They can help to provide valuable insights into people's perceptions, attitudes, and beliefs toward a particular subject matter, and can be an essential tool for identifying trends within a population (Creswell 2005). The use of a survey questionnaire in this research offers a variety of benefits. First, it is a cost-effective method of data collection, which means that it is less expensive than other research methods such as face-to-face interviews or focus groups . Second, it is less time-consuming than other methods, as respondents can complete the questionnaire at their convenience. Additionally, surveys enable researchers to collect a large amount of data from a broad range of respondents in a short period of time (Creswell 2014).

The questionnaire survey was preferred in the current study because it enabled the researchers to collect data from Ohio building inspectors who are located throughout the state. Distributing the survey to all inspectors across the state eliminated researcher sampling bias. The survey enabled the researchers to determine the level of adoption of RVIs in the state of Ohio and provided insights into the opinions, attitudes, and beliefs of the inspectors regarding the effectiveness and practicality of remote building inspections. Moreover, the survey allowed the researchers to compare the results with previous studies, providing an opportunity to identify trends in the population over time.

The questionnaire designed for this research included both open-ended and closed-ended questions (see Appendix). Closed-ended questions ask respondents to select from a set of predetermined answers or options. Some questions require respondents to select as many applicable options as feasible, while others require respondents to select only one option. Open-ended questions, on the other hand, give the respondent the opportunity to briefly explain or elaborate on a point or response. Questions X 10 and X 11 in the questionnaire used the Likert scale: a psychometric response scale that aids the researcher in determining the extent to which a respondent agrees with a statement (Likert 1932).

Data Collection

The questionnaire in the Appendix was used to gather information from Authorities Having Jurisdiction (AHJs) in Ohio. The questionnaire was designed to gather information on inspector's perceptions of the use of RVI. The questionnaire was also used to collect information from AHJs that have not adopted RVIs and their reasons for not adopting remote visual inspections. To maintain respondent anonymity, personal information was not captured in the questionnaire.

Pilot Testing the Survey Instrument

Validity and reliability are 2 crucial standards for questionnaire data collection, and researchers need to consider both group and individual responses. To ensure validity and reliability of a questionnaire, the researchers must conduct a pilot study and test the questions to ensure they are clear, understandable, and not misleading (Gall et al. 2003). Survey questions for the current study were developed following a comprehensive literature review. The draft questionnaire was reviewed by a select group of building inspectors, who suggested changes to ensure the questions would gather the information intended.

Administration of Survey Questionnaire

Survey questionnaires can be administered either online or offline. In this study, the questionnaire was developed using Google® Forms and distributed via email. This method was chosen for its convenience, cost-effectiveness, and ability to reach a broader audience, thereby increasing the potential response rate.

Data Analysis

Descriptive statistics, particularly frequencies and percentages, were used because they enable an understanding of the primary characteristics of the dataset.

RESULTS AND DISCUSSION

Survey response rate is an important indicator of representativeness and reliability. In this study, a total of 301 questionnaires were distributed, and 81 were returned and analyzed. This corresponds to a response rate of approximately 27%. According to Fosnacht et al. (2017), response rates of 20% to 25% are sufficient for confident analyses of data samples of less than 500. While a low response rate can be a cause for concern, it is important to note that the response rate alone is not a sufficient indicator of the quality of a survey (Cummings et al. 2001). In the context of the Ohio building inspectors' study, the low response rate may be attributed to factors such as time constraints, a lack of interest in the topic, or a perceived lack of importance of the survey. However, it is also possible that the respondents who participated in the survey were those most interested in RVIs and had strong opinions on the topic, creating potential for voluntary response bias.

Population of Municipalities

As shown in Fig. 1, most of the survey respondents (64%) were from municipalities with a population of between 10,001 and 50,000. Another 32% of the respondents were from jurisdictions with a population of 5,000 to 10,000 (11%), 50,001 to 100,000 (10%), and over 100,000 (11%). Only 4% of the respondents were from the smallest jurisdictions; those with less than 5,000 people.

Adoption of RVIs in the State of Ohio

The survey found that 40% of the respondents have adopted the use of RVIs while 60% have not (see Fig. 2). Results show 81% of the AHJs that have adopted RVIs did so in response to the COVID-19 restrictions, while the rest had been using RVIs prior to the pandemic. This represents a significant increase in the use of RVIs. When asked whether they intend to continue using RVIs after the COVID-19 pandemic, an overwhelming proportion (94%) indicated that they intend to continue using RVIs, while only 6% expressed their intention to terminate the use of remote inspection methods. This indicates that RVIs were effective and have the potential to be more widely used by building inspectors.

Twenty-five percent (25%) of the AHJs that have adopted RVIs said that they use them on more than 50% of their inspections; however, seventy-five percent (75%) use them on less than 50% of their inspections. No municipality used RVIs for all inspections. This indicates that while RVIs offer an alternative to traditional inspection methods, there are some inspections that must be done in person. This may be because some inspections need to be coupled with specific tests that must be performed on the job site. There is an opportunity for further investigation to determine what inspections cannot be done remotely and why.

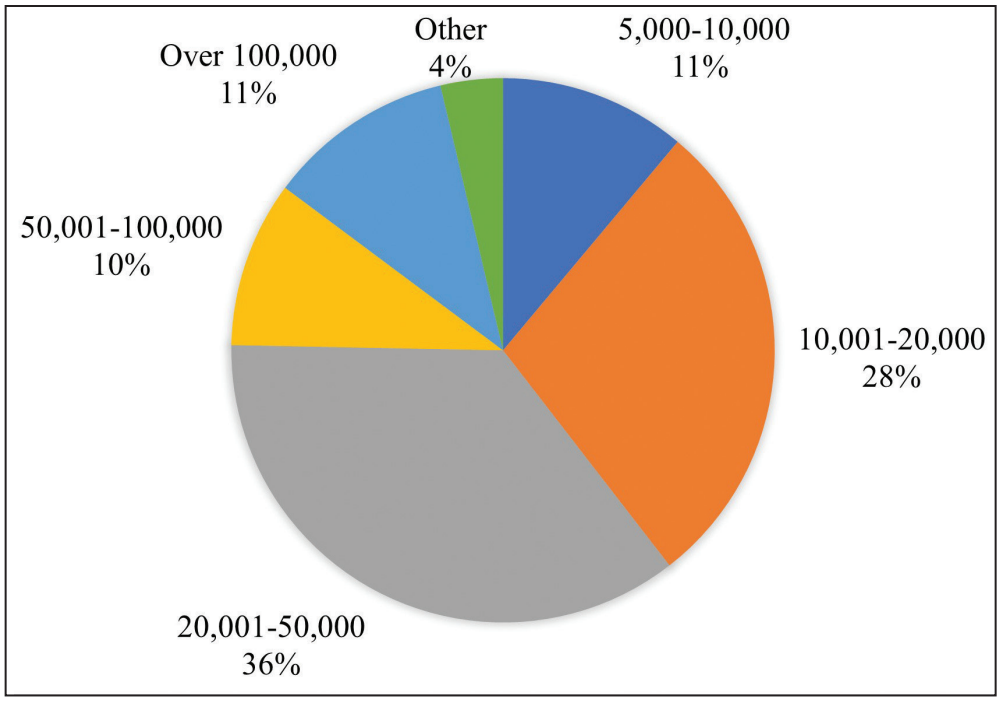

FIGURE 1. Proportion of survey respondents from municipalities with populations between 5,000 and 10,000 (dark blue), 10,001 and 20,000 (orange), 20,001 and 50,000 (grey), 50,001 and 100,000 (yellow), over 100,000 (light blue), and other populations (green)

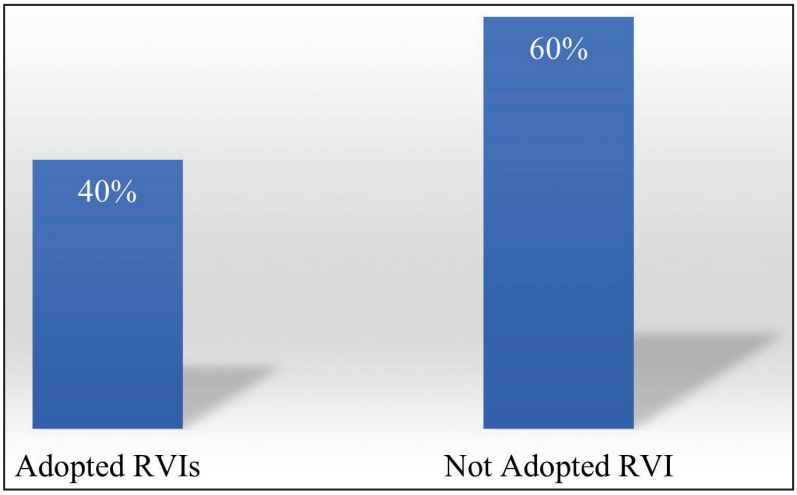

FIGURE 2. Percentage of all survey respondents that have adopted RVIs (left) compared to the percentage that have not adopted RVIs (right)

Availability and Use of Standard Guidelines for RVIs

The survey reported that 12% of the AHJs that have adopted RVIs use some guidelines, such as those from the International Code Council (ICC), for their remote inspections; however, 88% noted that they do not use any standard guidelines for remote inspections. When asked how beneficial municipality or state-specific guidelines on remote inspections would be, 19% said it would be extremely beneficial, 25% said very beneficial, and 47% said somewhat beneficial (Fig. 3). Only 9% of the respondents said that municipality or state-specific guidelines would not be beneficial. This highlights the need for some form of state-wide standardized inspection guidelines that can improve quality and efficiency in inspections.

Requirement to Use Specific Photo-Capture Technologies

Only 9% of the respondents indicated that they required some specific technology or technologies

(such as OpenSpace, Matterport, Multivista, and HoloBuilder®, etc.) for the inspections. It is possible that the inspectors in this survey were not familiar with the technology options available in the marketplace for RVIs. This finding may be an indicator of the need to educate Ohio inspectors on the available technologies, their capabilities, and their shortfalls. This will enable inspectors to make more informed decisions regarding adoption of RVIs.

Satisfaction with RVI Results

When asked how satisfied they were with the results of remote visual inspection, 3% of respondents said that they were not satisfied, 31% said that they were somewhat satisfied, 44% were satisfied, and 22% were very satisfied (see Fig. 4). This is an important finding because it suggests that RVIs are an effective way of conducting building inspections. An overwhelming majority (97%) indicated some level of positive satisfaction with the use of RVIs. This, coupled with the need for education on the available technologies and their potential, is a strong suggestion that RVIs have a role to play in the inspections of buildings now and will have an even greater role in the future.

LIMITATIONS

Limitations in this study mostly stemmed from the fragmentation of municipal governments and a general reluctance to respond to email surveys. The fragmentation of municipal governments across the state presented significant challenges to data collection. Organizational structures differ widely among local jurisdictions, influenced by factors such as population size, geographic location, and available financial resources. This variability often made it difficult to identify and contact the appropriate individuals to ensure accurate representation. In smaller municipalities, a single inspector may handle multiple responsibilities such as plumbing, electrical, and framing inspections; larger jurisdictions typically employ specialized inspectors for each discipline. Additionally, AHJs operate under varying scopes depending on local political structures, which makes it challenging to generalize their standard operating procedures across different jurisdictions.

Second, it was extremely difficult to obtain responses. Government-operated IT systems often instill a high level of caution regarding email communications, particularly those involving surveys or information requests. Just prior to our initial outreach, a cybersecurity breach had occurred within the state system, triggered by a malicious email survey link. In response, the state issued a mandate prohibiting interaction with unsolicited links, launched mandatory AHJ training sessions, and sent regular reminders warning staff not to open unknown email attachments or links. This significantly impacted the willingness of recipients to engage with our communications. To address

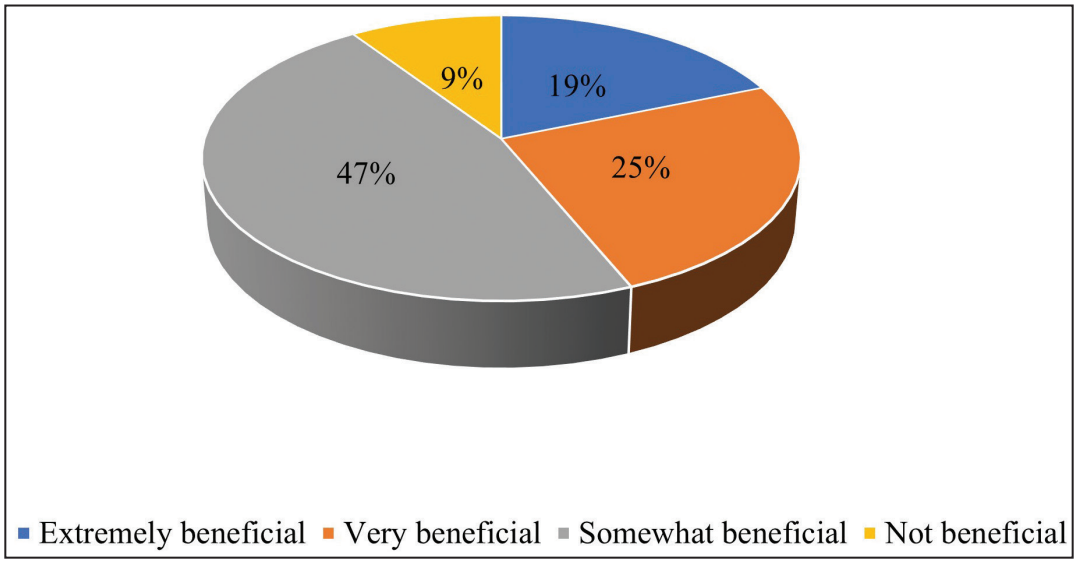

FIGURE 3. Anticipated impact of municipality/state-specific guidelines on RVIs. This graph displays the proportions (and percents) of survey respondents who indicated that the potential impact of implementing municipality and/or state-specific guidelines for RVIs would be extremely beneficial (blue), very beneficial (orange), somewhat beneficial (grey), and not beneficial (yellow).

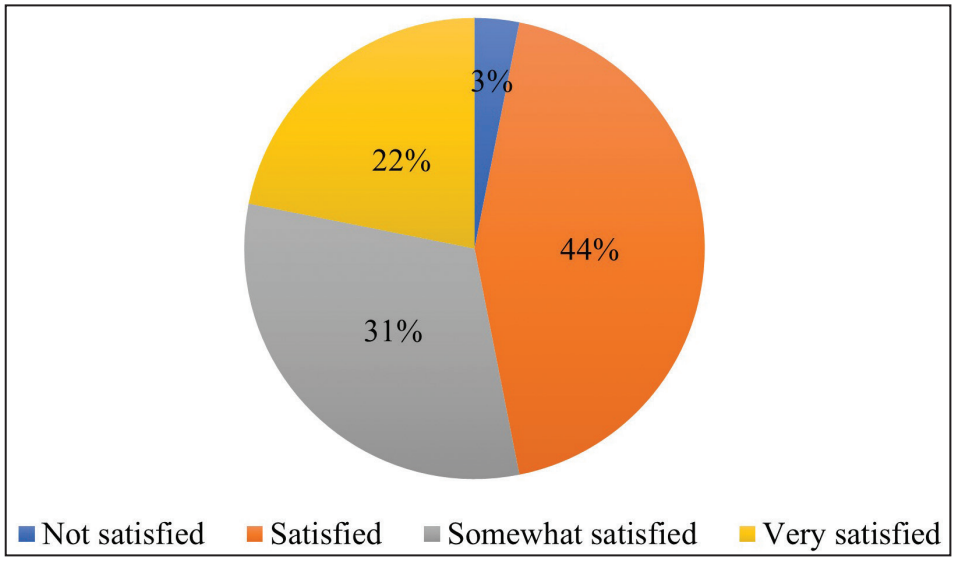

FIGURE 4. Level of satisfaction with RVIs. This graph indicates the proportion (and percentage) of respondents who indicated that they were not satisfied (blue), satisfied (orange), somewhat satisfied (grey), or very satisfied (yellow) with RVIs.

the low response rate, the Chief Inspector of the State of Ohio was contacted, who encouraged local officials to respond and reassured them of the email's legitimacy. This intervention helped secure a sufficient sample size. However, the situation highlights a broader challenge: data collection from AHJs is increasingly difficult, as most electronic communications are heavily filtered or viewed with suspicion due to cybersecurity concerns.

Finally, the response to this email survey was voluntary. When people self-elect to respond to a survey, and be part of a study, it is most likely because they are interested in the topic. They probably have very strong opinions about the study. This can have the negative effect of not being representative of the population because of voluntary response bias.

RECOMMENDATIONS

Findings indicate that municipalities are highly fragmented across the state, and it can be surmised that the same pattern exists from state to state. Thus, further examination at the state level and across the country is needed. However, federal oversight or guidelines seem to be nonexistent, or simply do not resonate with municipalities. Additional data from other states would allow for a more comprehensive understanding of RVI utilization across the country. Geographically, researchers could identify regional and demographic trends from this data, allowing for better development of guidelines that mitigate risk and guarantee safety.

The data indicate a need for further development of state-level guidelines for municipalities. More research and development at the state level is needed in Ohio to facilitate training, support education, and provide resources for municipalities interested in more widespread use of remote inspections. An investment in developing guidelines and remote inspection training could present many benefits for the state.

RVIs offer benefits that are beyond mainstream deliverables. Despite this, some respondents expressed concerns about trust and accountability, which they cited as reasons for resisting RVI implementation within their respective AHJs. However, RVIs can, in fact, enhance accountability by providing clear, high-definition documentation that verifies work has been completed to standard.

A notable example illustrating the need for such transparency is the Hard Rock Hotel collapse in New Orleans, Louisiana. The incident involved falsified city inspection reports, with inspectors claiming to have conducted on-site evaluations when they had not even visited the project. In contrast, RVIs create a verifiable digital record of inspections, promoting integrity and mutual accountability between contractors and AHJs.

Conclusions

Prior to the current study, no published data existed on Ohio's utilization rates of RVIs or broader trends related to their use in construction.

Despite the clear importance of understanding RVI implementation, limited information is available at the state, regional, or national level. This study contributes valuable insights by examining RVI use among AHJs across Ohio. A substantial percentage (40%) of municipalities across the state are already utilizing RVI technology, with most planning to continue using this method. Not only are AHJs using these methods, but they are also looking for further guidelines (90%) to direct their efforts as usage expands. Municipalities that use RVIs report a high degree of satisfaction with these technologies. The benefits of investing in RVI guidelines and resource development include providing wider potential labor pools for municipalities, ensuring critical documentation is taking place, and providing safe and reliable construction inspections.

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APPENDIX: QUESTIONNAIRE

RESEARCH TOPIC: OHIO BUILDING INSPECTORS' PERCEPTION OF REMOTE BUILDING INSPECTIONS.

INFORMED CONSENT TO PARTICIPATE IN RESEARCH

Principal Investigator: Lameck Onsarigo, Co-Investigator: Anthony Mirando, Key Person: Samuel Adu Asare

Kent State University Construction Management Professors are conducting research on the feasibility of advanced photogrammetry technologies for remote building inspections in Ohio. Please consider participating in the research by completing this survey.

Purpose
This study will investigate the perceptions of building inspectors toward the use of remote visual inspections. The study will also seek to establish protocols for effective remote visual inspection of building elements.

Benefits
This research will not benefit you directly. However, your participation in this study will help us to better understand the perceptions of inspectors on the use of remote inspections. The research may also help inform decisions on more effective inspection methodologies.

Risks
There are no anticipated risks beyond those encountered in everyday life.

Privacy and Confidentiality
Identifying information will not be included in the data that you provide. Your anonymity is further protected by not asking you to sign and return an informed consent.

Voluntary Participation
Taking part in this research study is entirely up to you. You may choose not to participate or you may discontinue your participation at any time without penalty.

Contact Information
If you have any questions or concerns about this research, you may contact Dr. Onsarigo at (lonsarig@kent.edu, or 330 672 0382) or Dr. Mirando at (amirando@kent.edu, or 330 672 1215). This project has been approved by the Kent State University Institutional Review Board. If you have any questions about your rights as a research participant or complaints about the research, you may call the IRB at 330-672-2704.

Consent Statement
My completion and return of this questionnaire will be indicative of my consent to participate in this research study.

SECTION A

1. What is the population of your municipality?
   - 5,000–10,000
   - 10,001–20,000
   - 20,001–50,000
   - 50,000–70,000*
   - Over 100,000
   - Other _____
2. Does your office accept any form of remote inspections?
   - Yes (proceed to section X)
   - No (proceed to section Y)

SECTION X

3. What level of remote inspections do you accept in your municipality?
   - All
   - Significant (over 50%)
   - Some (less than 50%)
   - None
4. Which of the following inspection types do you accept for remote inspections? (Check all that apply)
   - Plumbing
   - Electrical
   - HVAC
   - Life Safety
   - Framing
   - Insulation
   - Other _____

5. Was your decision to accept remote inspections occasioned by the COVID-19 pandemic?
   - Yes
   - No
6. Are/will you accept remote inspections post-COVID-19?
   - Yes
   - No
7. What quality of photo/video (image) do you accept (Check all that apply)?
   - 4K
   - 2K
   - 1080p
   - 720p
   - Other _____
8. Do you require the use of specific photo-capture technologies for the inspections (for example OpenSpace, Matterport, Multivista, HoloBuilder.)?
   - Yes
   - No
     (specify) _____
9. Do you have or have you adopted any standard guidelines for remote inspections on projects in your municipality (for example the ICC guidelines: "Recommended Practice for Remote Virtual Inspections.")?
   - Yes (specify)
   - No
     (specify) _____
10. How beneficial would municipality/state-specific guidelines on remote inspections be?
    - Extremely beneficial
    - Very beneficial
    - Somewhat beneficial
    - Not beneficial
11. How satisfied are you with the remote inspection results?
    - Not satisfied
    - Somewhat satisfied
    - Satisfied
    - Very satisfied
12. In your opinion, would statewide adoption of remote inspections make the career more attractive to inspectors?
    - Yes
    - No
13. In your opinion, what should be done to improve the effectiveness of remote inspections?

    _____
    _____

SECTION Y

3. What are the reasons behind not accepting remote inspections?
   - Contractors are not honest/trustworthy
   - Technology limitations
   - Staffing limitations
   - Lack of an industry standard/guideline
   - Other (specify) _____
4. Are there conditions that would enable you to consider accepting remote inspections?
   - Yes
   - No
     (specify) _____

* Numerical discrepancies for municipalities with populations of exactly 50,000 and those between 70,001 to 100,000 were addressed and corrected during data analysis.