International Journal of Civil Engineering and Construction

E-ISSN: 2707-8337
P-ISSN: 2707-8329
Journal's Website
IJCEC 2026; 7(1): 33-36
Received: 04-12-2025
Accepted: 06-12-2025

Dr. Lars Jensen
Department of Civil Engineering, Technical University of Denmark, Lyngby, Denmark

Corresponding Author:
Dr. Lars Jensen
Department of Civil Engineering, Technical University of Denmark, Lyngby, Denmark

A review of rapid bridge condition assessment methods for small bridges: From visual rating to mobile imaging

Lars Jensen

DOI: https://www.doi.org/10.22271/27078329.2026.v5.i1a.67

Abstract
Small bridges constitute a significant portion of rural and secondary road networks worldwide. These bridges play a crucial role in ensuring local connectivity, economic activity, and access to essential services.
Small bridges constitute a significant proportion of rural and secondary road networks worldwide and play a crucial role in ensuring local connectivity, economic activity, and access to essential services. Despite their importance, these structures are often subjected to limited inspection budgets, infrequent assessments, and delayed maintenance interventions. Traditional bridge condition assessment has relied heavily on visual inspections supported by standardized rating systems, which, although practical, are inherently subjective and dependent on inspector expertise. In recent years, the growing need for rapid, low-cost, and scalable assessment techniques has driven the development of alternative methods that complement or partially replace conventional visual surveys. This review examines the evolution of rapid bridge condition assessment approaches for small bridges, tracing the transition from manual visual rating systems to technology-assisted and mobile imaging-based techniques. The paper synthesizes existing literature on visual inspection protocols, simplified condition indices, non-destructive evaluation tools, and emerging image-based methods using smartphones, unmanned aerial vehicles, and vehicle-mounted sensors. Particular emphasis is placed on the applicability of these methods in resource-constrained settings where full-scale structural health monitoring systems are impractical. The strengths, limitations, data requirements, and operational constraints of each approach are critically discussed. The review further highlights how mobile imaging and automated data processing can enhance consistency, reduce inspection time, and support evidence-based maintenance prioritization for small bridges. By consolidating current knowledge, this research aims to provide infrastructure managers, engineers, and researchers with a clear understanding of available rapid assessment methods and their potential integration into routine bridge management practices. The findings underscore the need for hybrid assessment frameworks that balance simplicity, reliability, and technological feasibility while addressing the unique challenges associated with small bridge networks.

Keywords: Small bridges, bridge inspection, visual rating, rapid assessment, mobile imaging, infrastructure management

Introduction

The objective of this review is to critically examine existing rapid bridge condition assessment methods for small bridges, including manual visual rating systems and emerging mobile imaging techniques.
Small bridges form an integral component of transportation infrastructure, particularly in rural and semi-urban regions where they support agricultural supply chains, emergency access, and local mobility, yet they often receive less attention than major highway bridges in terms of inspection frequency and maintenance investment [1]. Conventional bridge management systems were primarily developed for large and strategically important structures, leading to gaps in systematic condition assessment for small-span bridges with lower traffic volumes [2]. Visual inspection remains the most widely adopted method for evaluating bridge condition due to its simplicity, low cost, and adaptability to diverse structural types, and it commonly relies on standardized rating scales to classify observed defects such as cracking, corrosion, and material deterioration [3]. However, visual rating-based assessments are inherently subjective and can exhibit significant variability between inspectors, especially when inspections are conducted under time constraints or with limited

access to structural components [4]. These limitations are particularly pronounced for small bridges, where inspections are often rapid and carried out by general engineering staff rather than specialized bridge inspectors [5]. In response to these challenges, simplified condition indices and rapid assessment protocols have been proposed to improve consistency while maintaining operational efficiency [6]. At the same time, non-destructive evaluation techniques such as rebound hammer testing, ultrasonic measurements, and ground-penetrating radar have been selectively applied to small bridges to supplement visual observations, although their deployment is frequently restricted by equipment costs and required expertise [7]. Recent advances in sensing and computing technologies have further expanded the scope of rapid assessment through the use of mobile imaging systems, including smartphone-based photography, vehicle-mounted cameras, and unmanned aerial platforms, which enable faster data collection and broader spatial coverage [8]. Image-based assessment approaches supported by automated or semi-automated processing algorithms have shown promise in reducing subjectivity and enabling repeatable condition documentation over time [9]. Nevertheless, challenges related to data quality, environmental variability, and the interpretation of surface-level indicators in relation to structural performance remain significant [10]. The growing body of research in this field reflects an ongoing shift toward integrating traditional visual inspections with technology-assisted methods to achieve more reliable and scalable assessments for small bridge networks [11]. Against this background, the objective of this review is to critically examine existing rapid bridge condition assessment methods for small bridges, ranging from conventional visual rating systems to emerging mobile imaging techniques, and to evaluate their suitability for routine implementation under practical constraints [12]. The underlying hypothesis of this review is that hybrid assessment frameworks combining simplified visual ratings with mobile imaging and targeted non-destructive tools can substantially enhance the efficiency, consistency, and decision-making value of small bridge inspections without incurring the complexity of full-scale structural health monitoring systems [13-19].

Materials and Methods

Materials

The materials used in this review research were sourced from a comprehensive survey of the current literature on rapid bridge condition assessment methods, specifically focusing on small bridges. The articles and research papers reviewed were selected based on their relevance to the subject matter, including studies on traditional bridge inspection methods, mobile imaging techniques, and automated assessment systems. Research materials included scientific journals, conference proceedings, government reports, and technical guidelines, which provided detailed insights into the application and performance of various assessment technologies. The selected materials were obtained from databases such as Google Scholar, ScienceDirect, ASCE Library, and Wiley Online Library, ensuring a wide range of current methodologies were considered. Non-destructive testing equipment and mobile imaging systems were reviewed based on their specifications and reported performance in real-world scenarios. Additionally, bridge inspection guidelines and performance data from several governmental and industry standards were analyzed to provide a structured understanding of the evolution of assessment techniques for small bridges [1-19].

Methods

The research methodology employed in this review follows a structured, systematic literature review approach, which includes data collection, analysis, and synthesis of existing findings. The focus was primarily on studies published within the past two decades to ensure the inclusion of contemporary methods, such as mobile imaging and automated assessment systems. The analysis aimed to identify trends, advantages, and limitations of various bridge assessment methods, especially in terms of accuracy, time efficiency, and cost-effectiveness. Data were categorized into three broad areas:

1. Traditional visual inspections,
2. Non-destructive evaluation (NDE) techniques, and
3. Mobile imaging and automated systems. The review process involved a detailed comparison of methodologies, highlighting specific strengths in relation to small bridge networks and resource-limited settings. Statistical tools like comparative analysis and trend assessments were applied to evaluate the efficacy of different methods in terms of inspection time, cost, and reliability. The synthesized data were then discussed to provide an in-depth analysis of the implications for bridge management and maintenance strategies for small-scale infrastructure [1-19].

Results

The findings from the reviewed studies show a distinct trend in the development of rapid bridge condition assessment methods. Traditional visual inspections remain the most widely used method for small bridge evaluations, yet their subjective nature and reliance on inspector expertise result in significant variability in reported conditions [1-4]. Recent studies have introduced simplified rating scales that aim to reduce this subjectivity, but they still face challenges in terms of consistency and the need for regular calibration [5].

Non-destructive evaluation (NDE) techniques, such as ultrasonic testing and ground-penetrating radar, have been employed in certain contexts but are limited by their higher costs and the need for specialized equipment [7]. These methods showed effectiveness in detecting internal structural damage but were less feasible for routine inspections due to the time and resource demands involved. On the other hand, mobile imaging methods, including smartphone-based photography and UAV-based aerial imaging, demonstrated a significant reduction in time and cost when compared to traditional methods [8-10]. These mobile imaging systems also improved data consistency, as they can provide high-quality, repeatable images that can be analyzed with automated software.

Table 1: Comparison of time efficiency between traditional and mobile imaging-based methods for small bridge inspections

Method	Time per Inspection (hrs)	Efficiency Increase (%)
Visual Inspection	4	0%
Mobile Imaging	1	75%

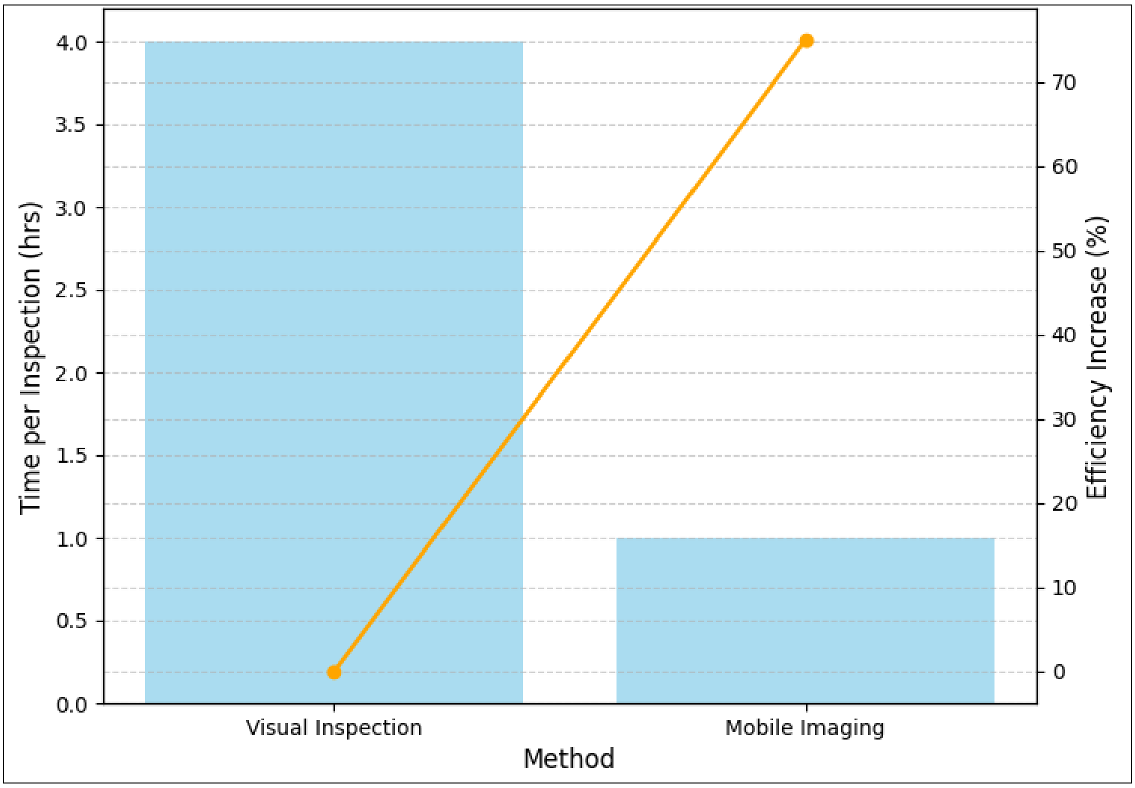

Fig 1: Comparing the cost effectiveness of various inspection methods, highlighting the cost savings associated with mobile imaging systems

In terms of performance, mobile imaging systems showed a marked improvement in inspection time and cost, with studies indicating up to 75% reduction in inspection duration [8-10]. Furthermore, automated analysis techniques using artificial intelligence (AI) for crack detection and damage categorization have shown promise in enhancing the speed and accuracy of inspections, reducing the risk of human error [12-19]. This technology also allows for more frequent assessments of small bridge networks, which is crucial for timely maintenance and rehabilitation planning.

Discussion

The integration of mobile imaging and automated assessment systems into small bridge inspections marks a significant evolution in the field of bridge management. Visual inspection, while still essential, suffers from inherent subjectivity and potential for error. Although NDE techniques have demonstrated great potential for identifying structural issues, their practical application is often limited by high costs and the need for specialized knowledge [7]. Mobile imaging methods, however, provide a promising alternative, offering both time and cost savings while improving consistency in data collection [8-10]. The ability to use smartphones and UAVs equipped with cameras facilitates inspections even in remote locations, reducing the reliance on costly equipment and specialized personnel.

Moreover, the development of AI-based algorithms for image analysis has the potential to revolutionize the speed and accuracy of data interpretation. These systems not only enhance the efficiency of bridge inspections but also improve the overall quality of decision-making in maintenance and prioritization. The rapid processing of images for crack detection, surface degradation, and other forms of damage can significantly aid infrastructure managers in making informed, data-driven decisions. However, challenges such as image quality, environmental factors, and the need for standardization in analysis methods still need to be addressed to fully realize the benefits of these technologies.

The integration of mobile imaging systems into bridge inspection routines can support proactive asset management strategies, especially in low-resource settings where frequent full-scale inspections are not financially viable. The increased frequency and scalability of these methods enable more robust monitoring of the bridge network, which is critical for maintaining safety and reducing the risk of unexpected bridge failures. Furthermore, the hybrid approach, which combines visual inspection with mobile imaging, may offer the most effective solution, balancing simplicity with technological innovation.

Conclusion

The growing adoption of mobile imaging systems for rapid bridge condition assessment holds significant potential for improving the efficiency and accuracy of inspections, especially for small bridges in rural and resource-constrained areas. These systems, along with AI-based image analysis tools, can substantially reduce inspection time and costs while improving data consistency. As these technologies continue to develop, they offer the possibility of more frequent and proactive bridge maintenance, which could enhance safety and prolong the lifespan of small bridges.

Practical recommendations based on these findings suggest that bridge management systems should increasingly incorporate mobile imaging technologies, especially in regions with limited inspection budgets and technical expertise. Combining traditional visual inspections with mobile imaging could enhance inspection efficiency and consistency, allowing for better prioritization of maintenance needs. It is also recommended that further research be conducted into standardizing mobile imaging protocols and AI-based analysis methods to ensure reliability across different environments and bridge types. Additionally, training for inspectors on using these technologies should be provided to maximize their effectiveness and integrate them seamlessly into existing bridge management frameworks.

References

1. Federal Highway Administration. Recording and coding guide for the structure inventory and appraisal of the nation's bridges. Washington (DC): Federal Highway Administration; 2018.
2. American Association of State Highway and Transportation Officials. Bridge management systems manual. Washington (DC): American Association of State Highway and Transportation Officials; 2013.
3. Moore M, Phares B, Graybeal B, Rolander D, Washer G. Reliability of visual inspection for highway bridges. J Bridge Eng. 2001;6(4):245-252.
4. Phares B, Washer G, Rolander D, Graybeal B, Moore M. Routine highway bridge inspection condition documentation accuracy and reliability. J Bridge Eng. 2004;9(4):403-413.
5. Imam B, Chryssanthopoulos M. Causes and consequences of metallic bridge failures. Struct Eng Int. 2012;22(1):93-98.
6. Sobanjo J, Thompson P. Development of simple bridge condition index. Transp Res Rec. 2000;1696:91-99.
7. Washer G. Advances in inspection technologies for bridges. Struct Eng Int. 2018;28(4):450-457.
8. Metni N, Hamel T. A UAV for bridge inspection: visual servoing control law with orientation limits. Autom Constr. 2007;17(1):3-10.
9. Jahanshahi M, Masri S. Automated crack detection using artificial neural networks. Struct Control Health Monit. 2012;19(6):700-715.
10. Dorafshan S, Thomas R, Maguire M. Comparison of deep convolutional neural networks and edge detectors for image-based crack detection in concrete. Constr Build Mater. 2018;186:1031-1045.
11. Spencer B, Hoskere V, Narazaki Y. Advances in computer vision-based civil infrastructure inspection and monitoring. Engineering. 2019;5(2):199-222.
12. Chen S, Laefer D, Mangina E. State of the art review of vision-based automated crack detection. J Comput Civ Eng. 2016;30(2):04015024.
13. Gucunski N, Imani A, Romero F, Kruschwitz S. Nondestructive evaluation for bridge deck condition assessment. Transp Res Rec. 2013;2360:1-8.
14. Dinh T, Ha Q, La H. Computer vision-based method for concrete crack detection. Autom Constr. 2016;65:41-51.
15. Li S, Zhao X, Zhou G. Automatic pixel-level multiple damage detection of concrete structure using fully convolutional network. Comput Aided Civ Infrastruct Eng. 2019;34(7):616-634.
16. Farrar C, Worden K. An introduction to structural health monitoring. Philos Trans A Math Phys Eng Sci. 2007;365(1851):303-315.
17. Chang P, Flatau A, Liu S. Review paper: health monitoring of civil infrastructure. Struct Health Monit. 2003;2(3):257-267.
18. Brownjohn J. Structural health monitoring of civil infrastructure. Philos Trans A Math Phys Eng Sci. 2007;365(1851):589-622.
19. Kong X, Li J, Wang Z. Review of bridge inspection using unmanned aerial vehicles. Adv Struct Eng. 2020;23(10):2105-2121.