Review of Asset Management System and New Implementation Model of a Case Study on Indonesian National Bridges

by

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ABSTRACT

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Effective bridge asset management has become increasingly critical in Indonesia as the national road network continues to expand and infrastructure investments rise to support economic growth, regional connectivity, and disaster resilience. Bridges constitute a vital component of this network, enabling mobility across Indonesia's diverse geography and supporting transportation corridors essential to economic activities. However, despite the increasing emphasis on infrastructure development, persistent challenges continue to limit the effectiveness of bridge management practices. These challenges include insufficient managerial capacity, inadequate technical resources, fragmented institutional responsibilities, and the absence of an integrated, standardized system capable of supporting long-term maintenance planning. As a result, many asset managers are constrained in their ability to apply data-driven decision-making frameworks, leaving Indonesia's bridge preservation activities largely reactive and budget-dependent.

Bridge asset management is a critical component of national road governance, requiring a reliable data input system to ensure accurate decision-making and the selection of appropriate preservation strategies for each structure. As of 2022, Indonesia's national road network spans 46,964 km and includes 19,241 bridges (6 meters and longer) under the management of the Directorate General of Highways at the Ministry of Public Works and Public Housing. To carry out bridge inspections, the Directorate General relies on consultants contracted directly by national road managers. This arrangement necessitates stringent oversight to ensure that field inspectors possess the required competencies and perform assessments to an acceptable standard.

In recent years, several unexpected bridge failures have occurred, primarily caused by overloading and scouring of bridge elements. These incidents prompted a reassessment of current bridge condition survey practices in Indonesia. The evaluation revealed several critical issues, most notably that inspectors often fail to conduct inspections with sufficient detail. This was evident from the large number of structural defects, many of them critical, that were not recorded in the detailed condition reports, despite requiring close examination.

Such omissions lead to highly subjective condition ratings and undermine the reliability of inspection results. As a consequence, when incomplete or inaccurate inspection data are used to support maintenance programming within Indonesia's bridge management system, the resulting decisions may be inappropriate or ineffective. These findings highlight the urgent need to strengthen inspection practices to ensure that maintenance planning is based on accurate, comprehensive, and objective condition information.

The development of Indonesia's bridge management system is still evolving and requires significant refinement. A variety of tools are currently used to assist managers in determining appropriate preservation strategies, yet the country is still in the process of formulating an accurate deterioration prediction model. Persistent challenges remain, particularly concerning the reliability of visual inspection data, which is frequently affected by inspector subjectivity. Additionally, the outcomes of bridge preservation programming have not been adequately validated through user feedback, leading these programs to be regarded more as budgetary limits than as technical planning references. In practice, many bridge managers still struggle to apply these preservation strategies effectively within the constraints of available funding.

The issues outlined above underscore the need for a comprehensive study aimed at improving the objectivity of bridge inspections in Indonesia. Such improvements will also support the development of decision trees and deterioration models, enabling bridge maintenance programming to become more accurate, efficient, and aligned with the goal of achieving optimal service life.

To conduct further analysis, a comparative asset management framework is required to evaluate the strengths and weaknesses of Indonesia's current system. A suitable benchmark is Japan's Bridge Management System, particularly that used in Kochi Prefecture. Kochi faces challenges similar to Indonesia in developing its bridge management system, but it offers a unique example due to its stand-alone platform capable of calculating 100-year life cycle costs using a high-precision LCC optimization program. This system evaluates each bridge element based on its actual physical condition, enabling managers to select appropriate maintenance actions, maintain bridge performance at predefined service levels, and determine the most suitable preservation strategies through straightforward condition corrections and cost estimations.

Although both Indonesia and Japan rely on visual inspection data as the basis for maintenance programming, their assessment approaches differ substantially. Japan employs a physical evaluation method that classifies deterioration strictly according to the type and severity of observed damage. Indonesia, by contrast, incorporates not only damage type and severity but also the functional role of the affected element and the potential impact on other structural components. As a result, Indonesia's approach is characterized as a non-physical method of assessing bridge element condition. This comparative analysis is essential to determining whether Indonesia's current bridge management system requires improvements to enhance the reliability of maintenance programming outcomes and ensure that resulting decisions are both technically sound and strategically appropriate.

To address these issues, this study provides a comprehensive evaluation of the current state of bridge asset management in Indonesia by investigating five essential determinants of management effectiveness: budget availability, data quality, policy framework, resource capacity, and the management system infrastructure. These determinants collectively shape the operational environment in which asset managers operate and fundamentally influence their ability to implement strategic maintenance planning. Within this framework, particular emphasis is placed on the behavioral dimension of asset managers' decision-making, which is examined using principles of the Theory of Planned Behavior (TPB). The study analyzes how three psychological constructs, attitude toward behavior, subjective norms, and perceived behavioral control (PBC), affect the intention to perform effective asset management. Findings consistently indicate that perceived behavioral control, mediated by factors such as budget stability, data reliability, and the availability of skilled personnel, functions as the strongest determinant. Compared to attitude and subjective norms, PBC exerts the greatest influence by enhancing the confidence of asset managers in their ability to perform inspection, prioritization, and planning tasks, particularly under resource-constrained conditions.

Parallel to the behavioral assessment, this study explores the applicability of Life Cycle Cost Analysis (LCCA) within Indonesia's bridge management context. LCCA has been widely applied in advanced asset management systems worldwide, particularly in Japan, where the High-Precision Life Cycle Cost Analysis (HP-LCCA) model has become a cornerstone of long-term infrastructure stewardship. Unlike traditional approaches, HP-LCCA integrates multi-segment condition evaluations of bridge elements, allowing deterioration to be assessed at a granular level. This segmentation method captures the spatial variability of damage across bridge girder components, offering more reliable predictions of future condition states and associated maintenance costs. The segmentation-based model has demonstrated strong capabilities in optimizing treatment timing, intervention selection, and cost minimization across the asset life cycle. This study evaluates how such a methodology could be adapted to Indonesia, where the existing Non-Physical evaluation model, characterized by aggregated scoring practices, may lack the precision necessary for high-resolution deterioration modeling.

A core component of the analysis involves a systematic comparison of Non-Physical and Physical visual inspection methods. Although these two approaches differ fundamentally in terms of assessment basis, scale, and damage quantification criteria, this study reveals that a generally linear correlation can be established between them. This correlation remains consistent across both concrete and steel girder bridges, indicating that Non-Physical evaluations can be meaningfully interpreted relative to the more detailed Physical method. However, the analysis also shows that variations in damage quantity and extent cause substantial divergence in objectivity between the two models. These discrepancies largely arise from the differing definitions of damage extent used in each method, which have implications for condition rating precision. The study finds that these methodological differences diminish significantly once segmentation is incorporated into the evaluation process. When condition assessments are performed at the segment level, both Physical and Non-Physical models converge more closely in terms of predictive alignment, demonstrating the value of adopting a more detailed evaluation framework.

The application of segmentation to bridge girder assessments produced notable improvements in the accuracy of Life Cycle Cost estimates. In particular, segmentation enabled the model to capture the localized distribution of deterioration, which is often obscured in aggregated condition ratings. This capability proved especially beneficial for bridges exhibiting non-uniform damage patterns, where deterioration is concentrated in specific segments rather than evenly distributed across an entire girder. For such cases, segmented HP-LCCA consistently produced minimum LCC outcomes, identifying targeted treatments that reduce unnecessary interventions and optimize long-term costs. Conversely, for bridges exhibiting uniform deterioration, segmentation yielded limited cost reduction benefits, suggesting that the value of high-precision modeling depends on the spatial characteristics of observed damage. Collectively, these findings reinforce the practical advantage of applying segmented Physical evaluations in Indonesia’s future bridge management framework.

The implications of this study extend beyond technical assessment to broader strategic and organizational considerations. By demonstrating a workable correlation between the Non-Physical and Physical models, this research validates the possibility of integrating Indonesia’s existing inspection system with a more advanced, high-precision deterioration modeling framework. This finding is crucial because Indonesia currently relies heavily on Non-Physical evaluations for nationwide inspections, and a complete shift to Physical evaluations would require substantial investments in training, tools, and human resources. The ability to bridge the two evaluation frameworks through correlation enables a transitional pathway, permitting Indonesia to gradually introduce higher-resolution methods without abandoning existing datasets or overwhelming local agencies.

Moreover, integrating segmented assessments into Indonesia’s bridge management system offers significant potential for improving objectivity, predictive accuracy, and budget efficiency. By shifting from generalized, assumption-driven deterioration estimates to models based on spatially detailed condition information, asset managers will be better equipped to prioritize interventions, reduce uncertainty, and justify budget needs based on quantifiable life-cycle benefits. This approach aligns with global best practices and promotes more transparent, accountable decision-making within the public infrastructure sector.

The behavioral component of this study provides further insight into the success conditions for implementing HP-LCCA. Asset managers’ willingness to adopt new methodologies is strongly shaped by perceived behavioral control, which is influenced by budget adequacy, data reliability, and the presence of qualified personnel. Thus, improving data quality through validation and verification processes, ensuring stable budget allocations for maintenance work, and strengthening the capacity of local inspectors and engineers are essential prerequisites for successful implementation. Without these enabling conditions, even technically advanced systems may fail to deliver their intended benefits.

Furthermore, the study identifies important psychological and organizational dynamics within the broader ecosystem of bridge management in Indonesia. Local inspectors, who are responsible for data collection, often face limitations related to workload, training, and consistency in visual evaluation. These factors influence the accuracy of Non-Physical assessments and, by extension, affect the reliability of deterioration modeling. Bridge experts and senior technical managers, while supportive of more advanced methods, are themselves constrained by inconsistent policies and uneven institutional support across regions. Consequently, national-level reforms must incorporate both technical adjustments and organizational capacity-building measures to ensure the long-term sustainability of improvement efforts.

The findings of this study contribute to the growing recognition that effective bridge asset management requires more than technological sophistication; it requires a balanced integration of behavioral readiness, data governance, institutional coordination, and financial sustainability. As Indonesia seeks to modernize its national bridge management practices, the adoption of HP-LCCA represents a significant opportunity to improve long-term performance and reduce maintenance expenditures through proactive planning and precision-based deterioration modeling. The study demonstrates that even within existing resource constraints, meaningful enhancements can be achieved through selective applications of segmentation and structured correlation between the two evaluation methods.

In conclusion, this research highlights the pressing need for Indonesia to establish a more standardized, objective, and data-driven bridge asset management framework. The correlation between Non-Physical and Physical evaluations provides a foundation for integrating current practices with more advanced methodologies, while segmentation enhances the precision of both condition assessments and cost estimations. The central role of perceived behavioral control underscores the importance of strengthening managerial confidence through improvements in budget stability, data quality, and workforce capability. The successful implementation of HP-LCCA within Indonesia’s bridge management system will not occur automatically; it will depend on deliberate institutional reforms, sustained capacity development, and a systematic alignment of policies, resources, and technological tools. Nonetheless, the findings affirm that with appropriate adjustments, Indonesia is well positioned to adopt high-precision deterioration modeling techniques that support more sustainable, cost-efficient, and adaptive bridge maintenance strategies for the future.

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LIST OF ABBREVIATIONS

AADT	Annual Average Daily Traffic
Avg_cost	Average LCC/maintenance
Avg_100	Average LCC/100-year maintenance
BMS	Bridge Management System
CS	Condition Score
FHWA	Federal Highway Administration
GIS	Geographic Information System
HP-LCCA	High-Precision Life Cycle Cost Analysis
iBMS	Intelligent Bridge Management System
LCC	Life Cycle Cost
LCCA	Life Cycle Cost Analysis
Max_cost	Maximum LCC
Min_cost	Minimum LCC
NP	non-physical, Indonesian visual assessment method (0-5)
P	physical, Japan visual assessment method (a-e)
Total_cost	Total LCC/bridge

CHAPTER I
BACKGROUND

1.1 Bridge Asset Management in Indonesia

Indonesia is an archipelagic country that has a diverse geographical structure, ranging from mountains, rivers, and oceans. From this geographical structure, there are quite a lot of obstacles in building a road network, so a supporting structure of the road network is needed. Bridges are one of the important elements in the connectivity of existing road networks in Indonesia, where the condition of the bridge needs to be monitored regularly and periodically. This bridge condition inspection activity is the spearhead in a bridge asset management system, as a determinant in the framework of the preservation program carried out every year.

Bridge asset management is an important part of national road governance activities, which requires a good data input system to support optimal results in determining the appropriate and appropriate preservation to be applied to each bridge. In 2022, the length of the national road network in Indonesia is 46,964 km and has 19,241 bridges (6 meters and above) which are included in the management of the Directorate General of Highways, Ministry of Public Works, and Public Housing. To carry out bridge inspection activities, the Directorate General of Highways is assisted by consultants who contract directly with national road managers. This condition requires extra supervision to ensure that inspectors who go to the field have good abilities.

In recent years, several sudden bridge failures have occurred, most commonly attributable to two factors: overloading and scouring of bridge elements. These incidents prompted an evaluation of the current bridge condition survey practices in Indonesia. The evaluation revealed several issues, most notably that inspectors often do not conduct sufficiently detailed inspections. This is evidenced by the significant number of structural defects that were not documented in the detailed bridge condition reports, including several critical elements that should have been examined closely.

Such omissions lead to highly subjective condition assessments and undermine the reliability of inspection results. Consequently, when these incomplete or inaccurate assessments are used as the basis for programming maintenance activities within Indonesia's existing bridge management system, the resulting decisions may be inappropriate or ineffective. This highlights the urgent need to strengthen inspection practices to ensure that maintenance planning is grounded in accurate, comprehensive, and objective condition data.

In its journey, the development of bridge management system still requires a lot of adjustments, where currently there are quite a lot of tools used to help managers determine bridge preservation strategies. Indonesia is currently in the developmental stage of identifying an accurate formula for predicting the deterioration of bridges. Several issues remain prominent in this area of research, particularly regarding the reliability of visual condition inspection data, which is often compromised by inspector subjectivity. Moreover, the outcomes of bridge preservation programming have yet to receive adequate feedback from users, resulting in these programs being largely disregarded as a planning reference and instead used merely as a budgetary cap. In practice, many bridge managers still do not fully understand how to implement these preservation programs within the constraints of the allocated budget.

The various issues mentioned above provide motivation for a comprehensive study to improve the bridge inspection system in Indonesia to be more objective. In addition, it can also assist in the preparation of decision-tree and deteriorating models to help bridge programming to be more precise and efficient, to achieve optimal bridge service life.

To conduct further studies, a comparative asset management system is needed to evaluate the existing asset management system in Indonesia. One asset management system that can be used as a comparison is the Bridge Management System in Japan especially in Kochi Prefecture. Kochi prefecture has the same issue for developing a bridge management system, also that is quite unique compared to other prefectures, where there is a stand-alone system that can calculate life cycle costs within 100 years with high precision Life Cycle Cost (LCC) optimization program, for each type of bridge element based on its physical condition in the field. This system helps managers to determine the right maintenance plan, to maintain bridge performance within a predetermined level of service, as well as accuracy in determining the type of maintenance with simple calculations to make corrections to assessments and estimates of maintenance to be carried out.

Both Indonesia and Japan rely on visual inspection results as the basis for bridge maintenance programming. However, there are significant differences in how condition assessments are conducted. Japan employs a physical method to identify damage to structural elements based on the type and severity of deterioration. In contrast, Indonesia not only identifies damage by type and severity but also evaluates the function of the elements and the impact of damaged structural components on other structural elements. Therefore, Indonesia is considered to employ a non-physical method in assessing the condition of its bridge structural elements.

This comparison is needed to test the extent of the existing bridge management system in Indonesia, whether improvements are needed to make the programming results reliable and can be used in making the right decisions.

1.2 Challenges in Current Bridge Management Practices

This research is one way to find out about the development needed in bridge asset management systems in Indonesia, based on several references to existing asset management systems in the world, one of which is the bridge asset management system in Japan. This is very necessary, considering the current condition of the inspection system in Japan has been used for more than 30 years, and until now the system has proven to be able to provide input to the value of more precise and efficient bridge preservation. To ensure the safety, security, and convenience of users in the bridge maintenance and management, and to realize a sustainable society and economy, technological development and standardization, inspection technology, and collection and communication of information are necessary.

Currently, Indonesia is still in a trial-and-error phase regarding bridge maintenance planning and programming for budgeting. This is evident from ongoing efforts to improve the systems used for these activities, which have been underway since 2017. However, the outcomes remain suboptimal. Despite the use of tools such as software applications for budgeting, bridge managers continue to rely on leftover funds from the central government. This often leads to misalignment between the necessary maintenance actions and the actual implementation, due to budgetary constraints. This situation has prompted researchers to investigate the factors that influence the behavior of bridge managers in asset management practices in Indonesia, with the goal of improving the system.

In addition, to support better bridge maintenance planning and programming, Indonesia is aiming to implement a new approach for predicting bridge condition deterioration. Currently, Indonesia utilizes an economic approach for bridge maintenance planning. This method is widely used in several countries such as the United States and the Czech Republic, where key factors considered include deterioration rate, discount rate, service life, uncertainty and variability, management strategy, agency and user costs, as well as vulnerability costs.

However, an alternative approach has been proposed by Japan, in which visual inspection data from the past 10 years can be used to predict the deterioration of bridge element condition ratings. This method is notably different from the economic approach, as it focuses on the condition ratings of structural elements as the basis for predicting bridge deterioration. These condition ratings also serve as key determinants for future maintenance plans. The condition ratings are the result of detailed visual inspections conducted on all bridge elements, particularly structural elements, which are critical and most indicative of potential bridge failure. The condition ratings are then processed using the Intelligent Bridge Management System (iBMS) to calculate the required Life Cycle Cost based on this data.

Indonesia has conducted detailed visual inspections and used condition ratings as a reference in bridge maintenance programming. However, can the results of these inspections be directly processed using iBMS? There are notable differences between the assessment methods used in Japan and Indonesia, which may require adjustments before the data can be effectively utilized.

Based on the explanations above, it is deemed necessary to conduct research to identify the key factors that determine the success of an asset manager in managing bridge infrastructure. Additionally, what adjustments are required for Indonesia to adopt the same Life Cycle Cost (LCC) calculation method used in Japan? These questions will be addressed in detail in the subsection on research questions.

1.3 Formulation of Research Questions and Key Issues

In order to clarify about the bridge management system issues in Indonesia and how it can be implemented in national bridge asset management system, this research background will be specific about how it implements this new system in Indonesia. Some issues that should be answered in this research is, what is the system characteristic?, how is the human resource capability?, what is the ideal organization to run this system?, what is the required performance levels for system function?, and how is the administrative/laws and regulation as variables. Based on the existing issues, several problems will be formulated in this study in the form of research questions, namely:

a. How can bridge asset management implementation be carried out effectively? What factors support the successful implementation of asset management?

Indonesia has had a Bridge Management System (BMS) since 1993, but since then there have been few changes in terms of predictive models for deterioration or effective bridge management strategies. Therefore, there is a need for development and improvement in bridge asset management by utilizing the latest technology. There are several factors that are presumed may contribute to difficulties in implementing bridge asset management, including insufficient funds allocated for bridge asset management, limited data available, a lack of experienced personnel in managing bridge assets, poor coordination among stakeholders, a lack of social awareness regarding bridge asset management at present, and some mismatch between system characteristics.

Through implementation research based on various social environment variables, this study will clarify the theoretical structure of implementation (customization) issues of bridge asset management system and will introduce new model, systems, and development technology.

b. How can differences in bridge condition assessment methods be implemented, and how will these differences affect Life-Cycle Cost Analysis (LCCA) calculations?

The condition assessment obtained in the field has not reached a satisfactory level of accuracy, therefore further research is deemed necessary to investigate the causes of this lack of accuracy. This inaccuracy results in fatal errors during the stage of predicting the deterioration of bridge conditions, causing a mismatch between the bridge management program and the actual conditions in the field. To reduce these errors, a current deterioration model is needed to calibrate the inaccurate values into a calibrated value by the model's research results. It is hoped that with this research, the assessment results obtained using the existing condition assessment system can be converted into a calibrated value and can be used to predict bridge condition deterioration more accurately and effectively.

1.4 Research Gap and Contribution

In the global research landscape, asset management remains one of the most critical aspects of infrastructure management. While numerous studies have addressed various challenges in this field, several fundamental issues continue to require deeper exploration. To effectively respond to the research questions outlined in the previous subsection, it is therefore essential to review recent literature in order to identify potential research gaps within the domain of bridge asset management.

In terms of asset management implementation, for a successful Bridge Management System (BMS) implementation, significant organizational change is necessary, and having a comprehensive change management strategy is crucial. This strategy should include clear goals, effective communication plans, structured training programs, and strong involvement from stakeholders like bridge engineers, asset managers, maintenance staff, and decision-makers [1]. Ensuring seamless integration of the Bridge Management System (BMS) within the organizational framework is imperative. This integration facilitates efficient data sharing, enhances workflow processes, and optimizes operational efficiency [2]. Regular monitoring and evaluation of BMS performance are equally essential. This practice allows for the identification of areas requiring improvement and ensures continued alignment with organizational objectives [2]. Given the dynamic nature of bridge management practices and technologies, regular updates of the BMS are indispensable. This involves incorporating new advancements, adhering to industry best practices, and drawing insights from prior experiences [2]. Additionally, fostering a culture of knowledge-sharing and collaboration among bridge personnel is paramount. This cultivates effective utilization of the BMS and nurtures key skills such as technical proficiency, communication, leadership, and problem-solving [3]. To summarize, seamless integration of the BMS, ongoing evaluation and updates, and promoting collaboration among bridge managers and staff are fundamental for enhancing operational efficiency and skill development.

Previous research has extensively discussed the successful implementation of bridge asset management using various methods, but it has not been specific enough to address asset management practitioners. Only a few references cited underscore the significant influence of asset managers in enhancing asset management practices. Nonetheless, the variability in individual asset managers' comprehension of the system has impeded the optimal effectiveness of bridge asset management. This study endeavours to rectify this issue by offering insights into the requisite characteristics of an ideal asset manager essential for the successful implementation of bridge asset management.

However, a noticeable gap exists in the literature: there is a dearth of research investigating the intention of asset managers regarding bridge asset management implementation. This deficiency underscores the necessity for comprehensive research endeavours aimed at elucidating the multifaceted factors that contribute to successful implementation. This unexplored dimension emphasizes the exigency for novel research initiatives within the academic sphere.

In the application of life cycle cost (LCC) analysis, various comparative studies have been conducted to optimize bridge span requirements, revealing that spans of less than 12 m with slab concrete superstructures are the most cost-effective option [4]. Moreover, the choice of material type—whether concrete or steel—has been shown to significantly influence LCC optimization [5]. In terms of maintenance strategies, preventive maintenance has consistently demonstrated its effectiveness in reducing total LCC. Furthermore, well-designed maintenance schemes can achieve an optimal balance between safety, cost, and environmental impact, thereby establishing preventive maintenance as a fundamental component of bridge life cycle management [6]. Despite these findings, previous research on bridge LCC has not examined the optimization outcomes by comparing different types of bridge condition assessments—namely, Physical and Non-Physical assessments—which could have a significant impact on LCC optimization. This gap in the existing literature underscores the necessity for further investigation.

From the review of previous studies, two major research gaps have been identified. First, there has been no comprehensive investigation into the behavior of asset managers and their intention regarding the implementation of asset management practices. Second, existing studies have not addressed the issue of life-cycle cost (LCC) optimization strategies—specifically, whether differences in bridge condition assessment methods lead to more optimal LCC outcomes. Based on these gaps, it is necessary to refine and update the research questions in this study, as follows:

Research Question 1 (RQ1): How do managerial behavioral factors, including attitude, subjective norms, and perceived behavioral control, influence the intention and decision-making processes of bridge asset managers in implementing a systematic bridge asset management system in Indonesia? What is the most important factors support the successful implementation of asset management? What should be done to ensure that an asset manager's capability supports more effective asset management implementation? What behavioral factors determine an asset manager's ability to implement asset management effectiveness?

Research Question 2 (RQ2): How can condition assessment differences be aligned to support asset management, and which approach (Physical or Non-Physical) provides the most optimal results? How can Life Cycle Cost be optimized and implemented? How to reduce the subjectivity of inspection result to support LCC optimization? How can the correlation between two different inspection methods produce optimal results? How can visual condition inspection results with segmentations influence LCC reduction? Which assessment method can produce the most optimal LCC?

1.5 Comparative Framework for System Implementation

This research will conduct international comparative research on system customization issues and introduction process issues related to the implementation of a road and bridge asset management system through concrete implementation in Indonesia. The Bridge Asset Management System in Indonesia has several unresolved issues, including inaccurate bridge condition assessment and a model of bridge deterioration that does not accurately depict the actual conditions. However, it appears that some of these issues can now be resolved by implementing the high-precision Life Cycle Cost (HP-LCC) program currently used by the local government in Japan's Kochi Prefecture.

The following is a research framework that will be carried out in several stages as follows:

1. Identifying the key issues that arise within a bridge asset management system and determining the objective and scope of this research.
2. Conducting a literature review is essential to identify existing research gaps and to formulate research questions that have not yet been addressed in previous studies.

3. Conducting an evaluation of the organization's current condition using various methods, such as questionnaires and interviews.
4. Collecting all relevant data related to bridge asset management, such as characteristics of bridges on national roads in Indonesia, bridge condition history, bridge preservation history, and preservation costs. Gathering data on bridge condition inspections conducted by bridge experts and comparing them with bridge inspector assessments to determine the degree of agreement in error values as a basis for correcting subjectively indicated values. Additionally, collecting interview and questionnaire data to assess the stakeholders' understanding level in bridge asset management, aiming to support the future implementation of high precision LCC in Indonesia.
5. Evaluating the implementation of the HP-LCC model in bridge asset management with Physical and Non-Physical evaluation method. Analyzing the model to obtain the most optimal bridge preservation values and validating the results to assess effectiveness and efficiency.
6. Performing correlation analysis on the results of the HP-LCC implementation trial using the available bridge asset management data in Indonesia. This analysis aims to determine the most significant factors that influence the final outcomes of the HP-LCC model.
7. Discussing the research findings and drawing well-structured conclusions to effectively address the research questions. Additionally, gathering feedback from stakeholders is crucial to identify necessary improvements and future enhancements, with the aim of refining and optimizing the system.

1.6 Objectives for Enhancing Bridge Management and Lifecycle Costing

The objectives of this study include providing an alternative to the latest bridge asset management model, in accordance with current needs, as well as providing an increase in the level of assessment objectivity in determining the value of the condition of the bridge. In addition, this research is also expected to provide the latest alternative conditions deterioration model to help bridge programming to be more effective and efficient.

To achieve this goal, it is necessary to carry out several research steps as follows:

1) Evaluating the current system characteristics, human resource capabilities, organizational structure, required performance levels for system function, and relevant government systems/laws will be conducted through interviews with bridge asset management practitioners in Indonesia.
2) Data will be collected through questionnaires to understand the behaviours of each asset management practitioner regarding bridge asset management. Additionally, an evaluation will be conducted on the condition assessment procedures carried out by bridge inspectors concerning various damage conditions in bridge elements, in order to determine the accuracy of their assessments.
3) An evaluation will be conducted of the bridge inspection methods used in both Indonesia and Japan by performing detailed visual inspections on selected bridges that serve as research subjects. This evaluation will provide insights for optimizing the use of bridge inspection guidelines.
4) An analysis will be conducted using statistical tools and bridge asset management tools to identify the necessary steps to achieve optimal value in bridge asset management.

5) A discussion will be conducted based on the research findings, along with providing recommendations to ensure the effective implementation of bridge asset management in Indonesia.

1.7 Overview of Dissertation Chapters

This dissertation will be presented as follows:

Chapter 1 Introduction, in this chapter will explain about the current issue, background, research framework, and research objective.

Chapter 2 Theory of Research, this chapter will explain about the fundamental concept of research, theory of planned behaviour (TPB), theory of bridge deterioration and life cycle cost, and condition assessment approaches.

Chapter 3 Methodology, in this chapter, the discussion will cover the methodology of the research, and discuss in detail about research design and framework, the procedural framework of data collection of intention analysis, and the procedures for data preparation and implementation of LCC.

Chapter 4 The Intention of Bridge Asset Management Implementation, in this chapter will explain the behavior of asset managers in executing bridge asset management, along with the factors that influence asset managers to improve the effectiveness of bridge asset management.

Chapter 5 Implementation of High Precision Life Cycle Cost Analysis (HP-LCCA), this chapter will explain the outcomes of applying High Precision Life Cycle Cost Analysis (HP-LCCA) in bridge asset management in Indonesia, the relationship between inspection models, and the results of LCC optimization based on analysis using available tools.

Chapter 6 Discussion and Conclusion, this chapter will present the analysis results in the form of a discussion, along with the conclusions drawn from the research conducted.

CHAPTER 2
THEORY OF RESEARCH

2.1 Fundamental Concept of Research

Bridge asset management is a method to ensure that bridge assets are in good condition, safe, and suitable for use. According to Gavrikova, E. et al. (2020), asset management is a systematic approach to developing, operating, maintaining, and divesting assets cost-effectively [7]. This approach involves strategic planning to maximize asset value over its lifecycle. Furthermore, Jung, H., and Kim, B. (2021) describe asset management as a tool to enhance decision-making and optimize maintenance strategies, aiming to achieve sustainable use and ensure the desired level of service at the lowest lifecycle costs [8]. Based on these descriptions, bridge asset management can be defined as a process that ensures asset conditions from the planning phase through to operations and maintenance, with the goal of delivering optimal value throughout the asset's service life. To achieve an effective asset management condition, a comprehensive evaluation is required, ranging from the organizational aspects of asset management to the tools and systems employed in the management process.

In the implementation of bridge asset management, several issues often hinder the effective management of assets. Common problems in bridge asset management include bridges reaching the end of their service life, technology integration, budget constraints, and discrepancies in data and field conditions. According to Furuta Hitoshi et al. (2007), there are complex issues when a significant portion of the bridge population approaches the end of its service life [9]. This situation can lead to a surge in the costs required for bridge maintenance occurring simultaneously. Such circumstances necessitate effective asset management to achieve efficiency in bridge management.

Additionally, with the rapid advancement of technology in recent years, there is a need to integrate these technologies with the existing traditional systems currently in use. According to Albanwan Areej (2024), specialized skills are required within bridge asset management teams to effectively integrate various technologies that can optimize the determination of maintenance needs and associated costs [10]. Cutting-edge technologies such as three-dimensional mapping, visual inspections using drones, structural monitoring with sensors, and other supporting technologies necessitate specialized expertise for their application in bridge asset management.

However, in some cases, this has not been fully supported by the availability of competent human resources capable of implementing bridge asset management using existing technologies. Another significant question is whether bridge managers have sufficient budgetary allocations to support asset management tools, enabling continuous operations.

Human resources in this context refer to bridge asset managers, who play a crucial role in making appropriate maintenance and rehabilitation decisions in accordance with the available budget. In Indonesia, many bridge managers lack specialized certification in the field of bridge management, resulting in implementations that often do not align with existing field conditions.

In addition, there is another issue regarding the use of technology as a decision-making tool. Asset management tools are utilized in various countries, including Indonesia and Japan. Both countries share a common problem—high levels of subjectivity in bridge condition assessments, which often lead to misaligned bridge maintenance planning. This issue is influenced by several factors, including the competency of Bridge Inspectors and the capability of the tools to evaluate the inspection results provided by the inspectors.

Currently, Indonesia still relies on a manual validation method, where the system is used but personnel are still needed to verify the validation results. This process is time-consuming, but it is effective in minimizing data input errors that may affect future programming needs. This approach differs from Japan's, where tools such as iBMS are used to automatically correct the condition assessments performed by inspectors. By simply inputting the current structural element conditions, the tool automatically adjusts the condition ratings based on historical inspection data for the same material type and damage category. With this advantage, the predictive condition assessments generated by iBMS are expected to aid in more accurate and efficient decision-making.

Based on the explanation above, it can be concluded that the role of human resources and asset management tools plays a crucial role that potentially impacts the implementation of bridge asset management. These two aspects serve as the focus of this study, with the expectation that the findings will contribute to the improvement of asset management practices, particularly in the context of bridge management in Indonesia.

For successful Bridge Management System (BMS) implementation, significant organizational change is necessary and having a comprehensive change management strategy is crucial. This strategy should include clear goals, effective communication plans, structured training programs, and strong involvement from stakeholders like bridge engineers, asset managers, maintenance staff, and decision-makers [1]. Their input and engagement greatly improve the system's effectiveness and acceptance. Providing thorough training to bridge staff is vital to ensure they understand and can use the BMS effectively. Moreover, ongoing technical support should be available to address any issues that may arise [1]. In summary, successful BMS implementation relies on thorough organizational change, stakeholder involvement, comprehensive training, and continuous technical assistance.

Asset managers often encounter decision-making challenges due to incomplete information stemming from the absence of a robust national bridge database or Bridge Management System (BMS), coupled with inadequate data on bridge conditions resulting from irregular monitoring practices [11]. To address this issue, a comprehensive deployment plan for the BMS is imperative, delineating specific steps, timelines, and responsibilities [12]. This plan should be tailored to accommodate the unique requirements of organization [12]. Adequate allocation of resources—financial, human, and technological—is crucial to ensure the effective functioning and sustained operation of the BMS [13]. In summary, enhancing decision-making in asset management necessitates meticulous planning aligned with organizational needs and the provision of ample resources to overcome challenges associated with the absence of a robust national bridge database or management system.

The need for maintenance funding has undeniably become a complex issue amid the economic challenges faced by several developing countries, including Indonesia. The growing number of bridge assets each year has led to another pressing issue: a significant number of bridges are nearing the end of their service lives. This situation mirrors that of Japan, where many bridges were constructed during the rapid development era of the 1970s, meaning that bridges built during this period are now, on average, around 50 years old. According to Nakashima et al. (2021), Japan faces an aging bridge problem, with the majority of its bridge population exceeding 40 years of age [14]. This has resulted in escalating preservation costs as bridge conditions deteriorate at an accelerated rate.

To reduce bridge preservation costs, Japan has developed various bridge asset management methods, including the Intelligent Bridge Management System (iBMS) application. This application is designed to predict bridge condition deterioration based on data collected over approximately 10 years. By utilizing this application, current bridge condition assessments can be refined and accompanied by probabilistic predictions of future deterioration. The predictions are then used to plan the timing and cost of necessary preservation activities to ensure that bridges reach their intended service lives while maintaining a predetermined level of service.

With the introduction of this application, Indonesia, currently working to improve its bridge asset management, can explore its potential for use in planning bridge maintenance, particularly along National roads. Additionally, given the similar issues Indonesia and Japan face concerning bridge age, this application is expected to aid in preservation planning tailored to the specific conditions of existing bridges.

However, implementing new technology is not straightforward, as it requires adjustments to the tools being used. Adaptations are necessary not only for the tools themselves but also within organizational elements, which must be carefully evaluated to ensure alignment with asset management process requirements. This consideration is crucial, as additional challenges—such as the preparation of bridge condition data—can also significantly impact the effective implementation of technology in bridge asset management.

The preparation of bridge condition data is a critical component in bridge preservation planning. Errors in conveying bridge conditions can lead to budget inefficiencies. According to Zakaria et al. (2022), conventional visual inspection methods are time-consuming, creating opportunities for inspectors to make recording errors [15]. Additionally, many bridge areas are difficult for inspectors to access, resulting in inaccurate condition data. This data inaccuracy presents a distinct challenge in bridge asset management, as it often leads to maintenance planning that fails to target the most pressing needs effectively.

The iBMS application can help mitigate these issues by distributing potential assessment errors according to a probability model of condition deterioration, one of the system's core calculations. For example, as shown in the figure 2-1, the condition rating "a" has probabilities for future deterioration outcomes as follows: a 10% likelihood of remaining "a," a 20% chance of becoming "b," a 10% chance of "c," a 40% chance of "d," and a 20% chance of becoming "e." This predictive deterioration model is based on a 10-year study of existing bridge condition data conducted in Japan.

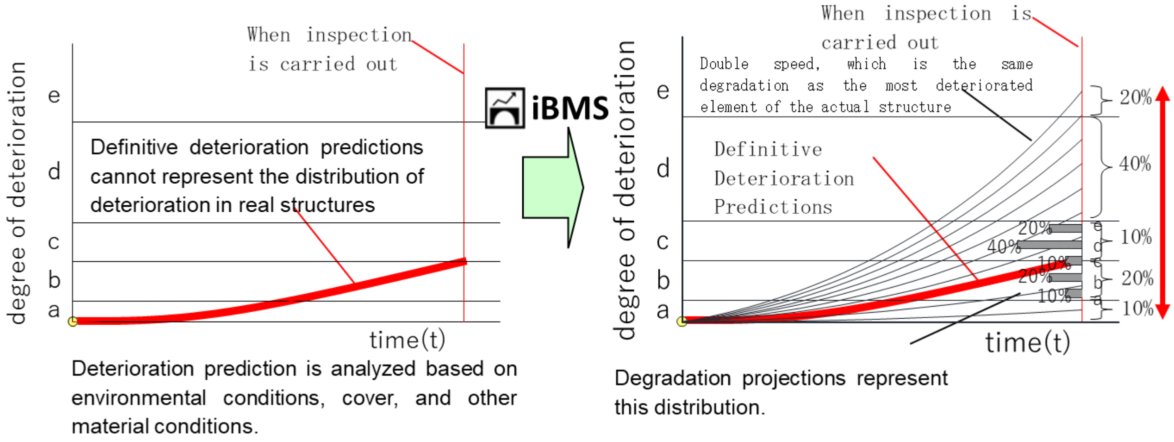


Figure 2-1. Example of variability in predicting deterioration.

Currently, Indonesia has a digital bridge asset management system, using applications for asset data collection, including asset inventory, condition assessments, and asset information. Asset condition ratings are based on evaluations of structural and non-structural elements, with structural elements playing a larger role in determining the overall condition of bridge assets. However, in maintenance planning, the condition rating applied represents the aggregate condition of the entire bridge structure, often leading to maintenance plans that do not align with actual needs. In contrast, Japan's approach focuses on each structural element individually, where damaged components directly influence bridge maintenance planning.

The model applied in Japan will be tested for implementation within Indonesia's bridge asset management system, with necessary adjustments to achieve optimal results. This study will outline several implementation steps, highlighting the differences in condition assessment systems between Indonesia and Japan. Japan employs a physical assessment method that focuses solely on structural element damage, whereas Indonesia uses a combined condition assessment approach, considering both structural and non-structural elements as well as their interrelationships—an approach that can be described as non-physical assessment. Due to these differences, adjustments are essential to optimize bridge maintenance needs accurately in Indonesia.

Through these adjustments, various requirements and critical factors for implementing the calculation model in Indonesia will emerge, supporting the Life Cycle Cost Analysis (LCCA) to obtain an optimal LCC value for a given bridge. This study will discuss the data used in these calculations and examine how effective data preparation can significantly contribute to optimizing the LCC process.

This study is fundamentally grounded in the Socio-Technical System theory, which emphasizes the improvement of asset managers' attitudes while optimizing the use of asset management tools to achieve the best outcomes in decision-making. According to Polojärvi et al. (2023), a socio-technical system is broadly defined as a system in which humans interact with technology, while more complex definitions also encompass organizational rules, environmental contexts, and emergent behaviors [16]. In line with this, Govers and Amelsvoort (2023) highlight that digital transformation must necessarily be accompanied by organizational transformation [17]. Furthermore, Gumede and Tladi (2023) describe a socio-technical system as one that involves both human and non-human elements, whose interactions produce specific outcomes [18]. The theoretical framework applied in this study is illustrated in Figure 2-2.

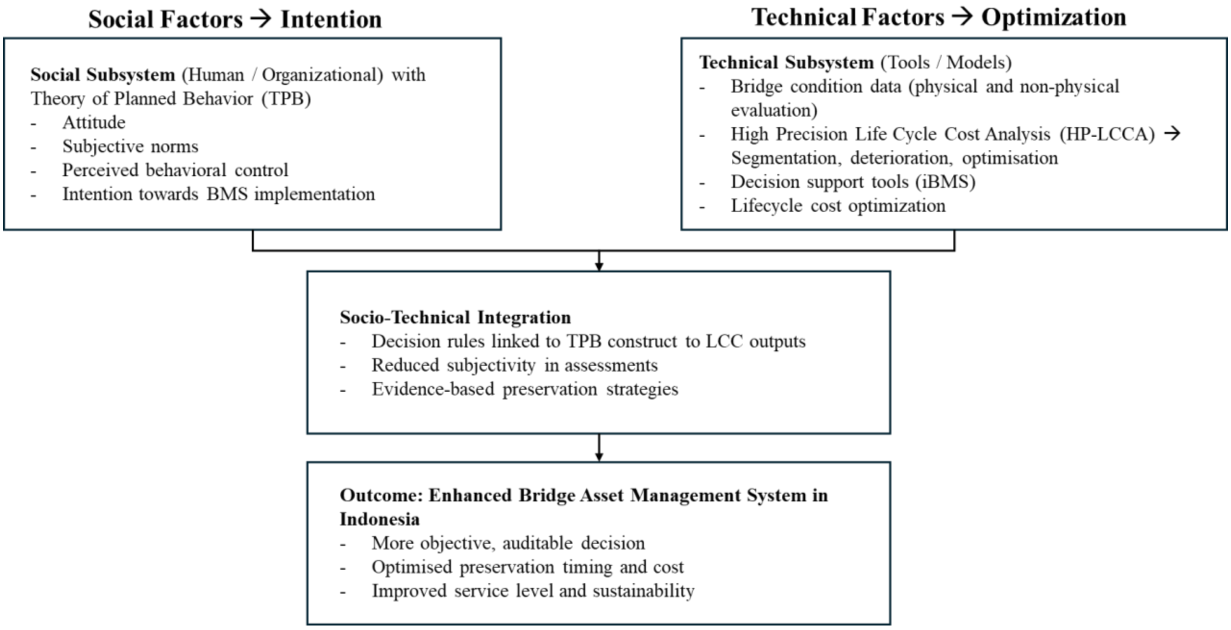


Figure 2-2. Socio-Technical System Theory

By examining the organizational behavior of asset management practitioners alongside the economic optimization of bridge preservation planning, this study expects that the integration of these two methodologies will yield optimal outcomes in the implementation of bridge asset management in Indonesia.

2.2 Theory of Planned Behaviour (TPB)

This study employs the Theory of Planned Behavior as shown on figure 2-3, which has not been previously utilized by researchers, to examine the correlation between the intentions of bridge asset managers to adopt bridge asset management in Indonesia. The goal is to ascertain the pivotal factors that impact the intentions of bridge asset managers, to ensure the efficacy and precision of bridge asset management in Indonesia.

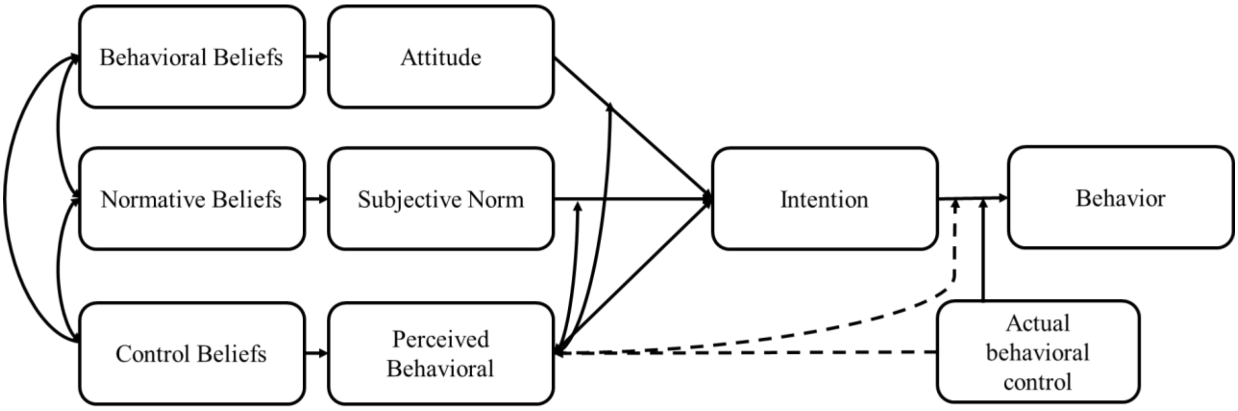


Figure 2-3. Theory of Planned Behavior (Icek Ajzen, 2019)

The Theory of Planned Behavior (TPB) is a well-known framework used to predict and explain human behavior in different areas [19]. It was developed in 1985 as an extension of the Theory of Reasoned Action [20]. TPB considers factors like personal attitudes, social influences, and perceived control to understand and forecast intentions [21]. It suggests that intentions are influenced by three main factors: attitudes, social norms, and perceived control [22]. Attitudes reflect how someone sees the behavior and its outcomes, social norms involve pressure from others to act or not act, and perceived control relates to someone's belief in their ability to perform the behavior [22]. These factors together shape a person's intention to do something. The TPB is widely used in various fields like psychology, sociology, medicine, and environmental studies [23,24]. It has been applied to study behaviors such as recycling and environmentally friendly purchasing [23,24]. Overall, the TPB offers a structured way to understand and predict human intentions, drawing on factors like attitudes, social norms, and perceived control. It finds broad application across different fields, aiding in analyzing behaviors such as recycling and eco-conscious purchasing.

Implementing asset management involves deciding how to use resources and man-age assets [25]. The Theory of Planned Behavior (TPB) can help organizations understand what influences these decisions and resource allocation. For instance, attitudes towards asset management can affect how resources are prioritized and how much investment goes into managing assets [25]. The expectations and opinions of stakeholders, known as subjective norms, can also influence asset management decisions. Another important factor is perceived behavioral control, which reflects how confident someone feels about managing assets effectively and dealing with challenges [21]. In summary, using the Theory of Planned Behavior (TPB) can help organizations understand how attitudes, subjective norms, and perceived control affect decision-making and resource allocation in asset management, highlighting the importance of TPB in improving asset management practices.

In conclusion, the Theory of Planned Behavior offers useful insights for implementing asset management in organizations. By examining attitudes, subjective norms, and perceived behavioral control as factors influencing the intentions of bridge asset managers, organizations can grasp how decision-making, resource allocation, and competency development in asset management are influenced. This understanding can guide strategies to encourage positive intentions and behaviors, ultimately enhancing asset management practices' effectiveness.

2.3 Theory of Bridge Deterioration and Life Cycle Cost

In predicting deterioration, historical data and various statistical methods can be employed to enhance the accuracy of a deterioration model [26]. A deterioration model is an approach used to forecast the degradation of infrastructure over its lifespan. Several commonly used approaches for deterioration modeling include deterministic models (such as regression), stochastic models (such as Markov chains), or artificial intelligence models. Each model has its strengths and weaknesses, as illustrated in Table 2-1.

Table 2-1. Evaluation models pros and cons

Models	Pros	Cons
Deterministic	Easy to compute and apply, straightforward calibration with available software, and useful for predicting future conditions	Do not account for random errors in prediction, lack flexibility, and may not be reliable due to not considering

Models	Pros	Cons
	based on perfect knowledge of variables.	uncertainty or unobserved variables.
Stochastic	Account for inherent uncertainty and variation in deterioration factors, use present condition to predict future state, and computationally efficient for large networks.	Assumption of fixed inspection intervals may lead to inconsistent predictions, and the Markov chain approach ignores previous states of bridge condition.
Artificial Intelligence	Utilize high processing speeds, capable of mimicking past patterns of deterioration, and can overcome some shortcomings of current models.	Still requires further research for enhancement, verification, and validation in real-world environments. May share limitations of deterministic models.

According to Malik M. and Armor B. (2024), the issues necessitate preventive, cyclic, or condition-driven maintenance measures to extend the service life of the bridge. Common types of damage in concrete bridge structures include concrete cracking, spalling, and surface deterioration due to environmental factors [27]. These types of damage can cause a significant decline in the condition of the bridge over the years.

To obtain a good model, it is crucial to have well-validated historical bridge condition data. Additionally, selecting independent data is necessary to ensure that these elements significantly influence the deterioration of bridge conditions. It's important to note that not all data available in bridge inspection databases contribute equally to condition deterioration, thus careful consideration is essential.

In this study, the deterioration prediction of a bridge girder element is performed using a deterministic model, where the physical deterioration model of the bridge over the years becomes the predictive model utilized in the iBMS application, specifically for the girder structural elements. However, for other elements such as bearings, substructures, and slabs, the application employs a stochastic model using the Markov model. As illustrated in Figure 2-4, which shows the soundness damage on the concrete surface due to rebar corrosion, with the probability transition of deterioration from a good condition (Condition I) to a worse condition (Condition III).

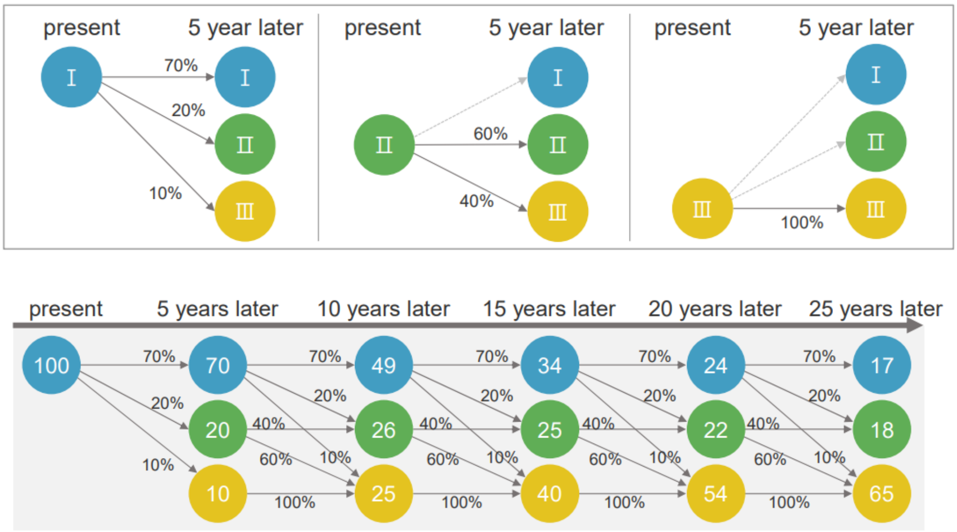


Figure 2-4. Example of estimating element deterioration based on Markov model

According to Torti et al. (2022), life-cycle cost analysis (LCCA) is a method used to evaluate the total investment cost of transportation bridges [28]. Meanwhile, Mortagi (2021) suggests that in the face of various changes such as climate change and seismic activity, LCCA can assist in predicting the necessary preservation costs for bridges [29]. Lei, X., et al. (2022) define life-cycle cost as the total expenses incurred over the entire lifespan of a bridge, including inspection, repair, and replacement costs [30]. This is calculated by summing up the annual maintenance costs for each bridge, taking into account factors such as labour, materials, and equipment. Based on these sources, it can be concluded that life-cycle cost analysis is a decision-making tool for maintenance planning and optimizing preservation costs effectively.

Several studies have identified different LCCA models, one of which is a probabilistic-based framework designed to evaluate the total cost required over the bridge's service life. Additionally, LCCA generally requires various data inputs, such as deterioration rate, discount rate, service life, uncertainty and variability, management strategy, agency and user costs, and vulnerability costs. This approach differs significantly from the model used in Japan, where structural elements are divided into numerous segments, leading to differing deterioration models between segments depending on the type and severity of damage, as illustrated in

Figures 2-5. Moreover, detailed material information on structural elements, such as concrete and steel, is considered to account for potential corrosion. Repair history is also incorporated into the analysis as a corrective action to better reflect the condition of the elements.

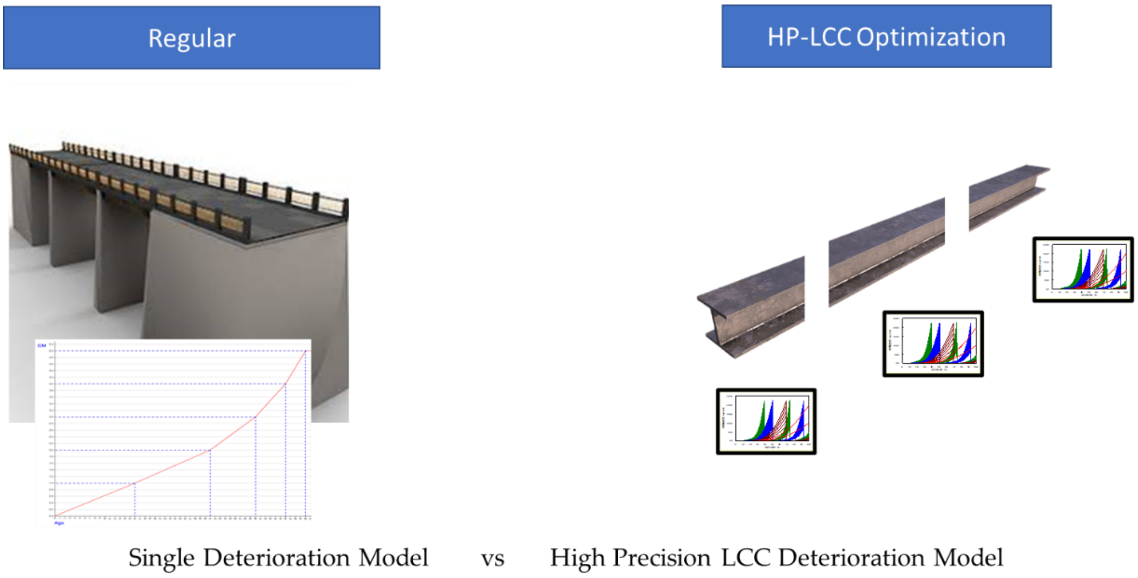


Figure 2-5. Single-Bridge deterioration model vs. High-Precision LCC deterioration model

By applying the High-Precision Life Cycle Cost (HP-LCC) calculation method, bridge deterioration modeling is expected to become more segmented, focusing only on areas where damage is present. Segments that remain undamaged will follow a different deterioration prediction model, allowing each portion of the structure to be evaluated according to its actual condition. This approach is anticipated to yield lower overall Life Cycle Cost (LCC) values by preventing unnecessary maintenance actions on segments that do not require intervention.

2.4 Condition Assessment Approaches

The BMS used in Indonesia is the result of collaboration with the Australian Government in 1992 and is still used as a guideline for bridge inspections in Indonesia until now. In the 1992 BMS, for detailed inspection and evaluation of bridge conditions, the structure is divided into 5 hierarchical levels of elements, with the highest-level being level 1, which is the bridge itself, and the lowest level being level 5, which refers to individual small elements and components of the bridge. For damaged elements, a condition assessment needs to be provided.

The assessment system for damaged elements consists of a series of questions regarding the structure's condition (S), level of damage (R), quantity of damage (K), element functionality (F), and the influence of damage on other elements (P). Each value is assigned a 1 or 0 at each hierarchical level of the bridge, starting from the lowest level (level 5) up to the highest level (level 1) [31]. Elements or groups of elements are evaluated by assigning a Condition Value ranging from 0 to 5. These numbers represent the sum of the five values determined according to the criteria provided in Table 2-2.

Table 2-2. Bridge assessment criteria in Indonesia

Component	Assessment Criteria	Condition State
Nature Mark (S)	Harmful	1
	Otherwise	0
Degree Mark (R)	Heavy	1
	Light	0
Extent Mark (K)	More than 30% for structural and 50% for non-structural element	1
	Less than 30% for structural and 50% for non-structural element	0
Function Mark(F)	Element is still functioning.	1
	Otherwise	0
Implication Mark (P)	Influencing other element or traffic	1
	Otherwise	0
Condition Mark (CM)	NK = S+R+K+F+P	0 – 5

The condition assessment is conducted hierarchically, starting from individual elements referred to as Level 5. It then progresses to groups of similar elements at Level 4, followed by Level 3, which groups elements within a system. Next is Level 2, which includes bridge components such as the superstructure, substructure, and other bridge components. Finally, Level 1 represents the overall condition of the bridge. It is important to note that this assessment takes the worst condition rating from the structural elements that exhibit damage.

After assessing the elements at level 5, 4, or 3, the Condition Value for elements at higher levels in the hierarchy is determined by evaluating the extent to which the damage in the lower-level elements affects the higher-level elements, whether these elements can function properly, and whether other elements at higher levels are influenced by these damages. This process helps obtain the Bridge Condition Value at level 1, which, when used in conjunction with the Bridge Management System, can determine the maintenance strategy for the respective bridge.

The explanation of condition mark of elements or bridges is as follows:

0 New condition with no defects
1 Very minor defects, do not affect safety or function of the bridge
2 Light defects which require monitoring or maintenance in the future
3 Heavy defects which require attention soon, which may become serious within 12 months
4 Critical condition, serious defect that affect safety and the function of the bridge
5 Collapsed, or no longer functioning.

The current assessment of bridge conditions utilizes a bridge inspection application called INVIJ. This application has been in use since 2018 for inputting bridge condition data and directly uploading it to the bridge database. Currently, the process of data validation and verification is still performed manually, necessitating the need for a model that can be used for automatic validation of bridge condition data.

Table 2-3. Bridge maintenance action in Indonesia

Parameter	**Condition Mark**	**Category**	**Maintenance Action**
Bridge Condition	0 – 2	No defect – Light defect	Routine / Periodic Maintenance
	3	Heavy defect	Rehabilitation
	4,5	Critical/Collapsed	Replacement
Traffic	0	Fit	Routine Maintenance
	5	Too narrow	Duplication, Replacement, Widening
Load	0	Appropriate	Routine Maintenance
	5	Inappropriate	Strengthening or Replacement

To identify bridge maintenance needs from the available data, a comprehensive assessment of the condition is required based on various assessment parameters, including bridge condition, traffic, and load. The assessment criteria can be seen in Table 2-3.

In contrast to the approach taken in Indonesia, the assessment of bridge conditions in Japan focuses on the structural elements of the bridge. These structural elements include the deck, girders, piers, foundations, and abutments. According to the bridge inspection guidelines issued by the Ministry of Land Infrastructure and Transportation (MLIT), bridges that are over two meters in length are inspected once every five years. Direct visual and close-range inspections are necessary to assess the level of damage occurring in the examined elements. Simple tools and equipment are brought along to aid inspectors in determining the precise level of bridge damage. For each structural element, the assessment of its condition is based on its importance and the urgency of necessary repairs. The following are the procedures used for health diagnosis on bridges in Japan, as seen on table 2-4 and 2-5 [32]:

Table 2-4. Bridge assessment categories in Japan

Category		Condition
I	Healthy	Conditions that do not disrupt the structural functionality.
II	Prevention Stage	Conditions that should undergo preventive maintenance actions even if there is no disruption to the structural functionality.
III	Early Maintenance Stage	Conditions that require early intervention due to the potential for disruption to the structural functionality.
IV	Emergency Treatment Stage	Conditions that require emergency intervention due to a high probability or already existing disruption to the structural functionality.

Table 2-5. Assessment categories for each bridge elements in Japan

Assessment Category	Element Condition
a	No defect
b	Minor defect depth & Minor defect area
c	Minor defect depth & Major defect area
d	Major defect depth & Minor defected area
e	Major defect depth & Major defected area

Bridge condition assessments in Japan focus on evaluating the structural elements of bridges. Japan utilizes a physical model approach, emphasizing specific types of damage affecting each structural element individually. This approach is also evident in the more detailed segmentation of bridge elements compared to the assessment models used in Indonesia.

Based on the explanation in the previous paragraph, it can be concluded that element condition assessment in Indonesia reflects interdependencies among structural elements. This interdependence encompasses not only the type of damage, the severity level, and the extent of damage, but also the extent to which damage in one element is judged to affect other elements. Consequently, the assessment is not interpreted as purely a direct outcome of the observed damage alone. This approach differs from the practice in Japan, where condition assessment focuses primarily on the physical condition of the structural element within the specific segment under inspection. Accordingly, the Indonesian approach is characterized as a Non-Physical evaluation model, whereas Japan applies a Physical evaluation model.

2.1 Synthesis of Research Theory

The implementation of bridge asset management faces a series of issues, one of which is the insufficient understanding of effective asset management processes by human resources. Asset managers and field inspectors play critical roles in this process, with inspectors responsible for accurately reporting the condition of bridges on-site, and managers tasked with determining the necessary interventions. The inability of one or both of these key figures can result in invalid data, leading to erroneous decision-making. The motivation and intent of an asset manager are key indicators of the success of bridge asset management implementation. Therefore, it is important to identify the factors that drive an asset manager to effectively apply bridge asset management practices.

Additionally, the tools used to assist asset managers in calculating maintenance cost requirements rely heavily on accurate data supplied by inspectors. This process becomes challenging when data corrections are performed manually, as is currently the case in Indonesia. Therefore, with the implementation of iBMS in bridge asset management in Indonesia, it is expected that several issues related to subjectivity in assessments and inaccuracies in maintenance budgeting can be addressed. However, since iBMS is a tool developed in Japan with a different inspection guideline background than that of Indonesia, adjustments are necessary. Further research will be conducted to ensure that the system's implementation will prove to be more accurate and efficient.

CHAPTER 3
METHODOLOGY

3.1 Research Design and Framework

The research methodology that will be taken to solve the problems in the research question that has been defined in the previous chapter. The approach used in this study is qualitative and quantitively. In this case, a qualitative approach by utilizing the experience of experts in bridge inspection and structural analysis through questionnaires. This aims to get an overview and view of respondents on the reviewed objects. Meanwhile, a quantitative approach is employed to obtain the visual condition of bridges through selected field data samples, which are subsequently used to predict the preservation costs over their service life, serving as a basis for decision-making and the formulation of appropriate preservation strategies. In addition, a comparative study was also conducted between BMS used in Indonesia (Non-Physical evaluation) and BMS used in Kochi Prefecture, Japan (Physical evaluation), to obtain the latest findings related to the development of BMS in the future.

The implementation of bridge asset management in Indonesia still faces several challenges, including the subjectivity of bridge condition assessments, uncertified inspector capabilities, inadequate availability of inspection tools, insufficient mastery of bridge asset management systems by administrators, limited budget availability, and poorly structured policies in bridge asset management.

In bridge asset management, asset managers play a crucial role in ensuring better and more optimal asset management. However, this must be supported by factors that influence the behavior of asset managers to achieve more effective bridge asset management. To identify the factors that influence bridge asset managers in performing their duties, in-depth research is necessary. One method that can be used for such research is the Theory of Planned Behavior

(TPB), which is commonly applied to understand the factors that most influence an individual's attitude toward a specific activity.

Bridge asset management inevitably involves several key issues, one of which is the subjectivity in assessing the condition of bridge elements, which requires appropriate solutions. To gain deeper insight into the issues surrounding bridge condition assessments, it is essential to compare them with other methods that are considered to produce more objective results. Japan employs a different assessment method compared to Indonesia, focusing primarily on structural bridge elements such as decks, girders, piers, abutments, foundations, and other structural components, commonly referred to as the Physical Assessment Method.

Unlike in Indonesia, where bridge condition assessments are conducted by assigning values to various damage factors such as type of damage, severity, extent, functionality of the element, and impact on adjacent elements, a hierarchical system is also applied to determine the overall condition rating of the bridge under review. This hierarchy begins at level 5, which focuses on the most detailed bridge elements, such as the deck, girders, and other components, along with the location of their damage. These values are then compared across other elements at levels 3 and 4. The elements are subsequently grouped into larger bridge components, such as the superstructure and substructure, at level 2. After comparing condition ratings across different elements, a final condition rating is determined at level 1, based on the worst condition rating from the previous levels. This approach shows that bridge condition assessment in Indonesia is not solely based on the type and severity of damage but also takes into account other elements in determining the final rating. This assessment method is referred to as the Non-Physical method.

To determine the level of objectivity between the Non-Physical and Physical assessment models, further research is necessary. To achieve this, a comparison between the two models must be conducted on the same observation object, allowing for an evaluation of which model provides a more objective assessment of bridge elements. This comparative method can be implemented by presenting a series of photos of damaged bridge elements, accompanied by descriptive explanations of the damage, to bridge inspectors. These inspectors, who are experienced in bridge condition assessment, will be asked to complete a questionnaire. The bridge inspectors participating in this questionnaire must have expertise in one of the assessment methods (Non-Physical or Physical). The questionnaire results will then be analyzed statistically to evaluate the objectivity of the assessments and to explore the correlation between the two assessment methods.

The results of this comparison will also be analyzed using correlation analysis, which will indicate the strength of the relationship between the variables compared between the Non-Physical and Physical assessment results. The aligned values will then be used to calculate Life Cycle Cost (LCC) using the iBMS application on several bridge samples selected as study objects.

3.1 Methodological Framework for Analysis

3.1.1 Procedural Framework for Data Collection of Intention Analysis

This study endeavors to construct a comprehensive model elucidating the intentions of bridge asset managers and their readiness to implement bridge asset management practices in Indonesia, with a particular focus on national road segments. Employing a mixed-method approach that seamlessly integrates qualitative and quantitative methodologies, we aim to delve deep into the underlying factors shaping asset managers' attitudes, subjective norms, perceived behavioral control, and overall willingness to engage in effective bridge asset management.

In the qualitative phase, insightful interviews were conducted with 14 seasoned senior bridge asset managers at the Directorate General of Highways, each boasting over 15 years of invaluable experience in the field. These interviews, meticulously structured to unearth the nuances of bridge asset management in Indonesia, provided rich data on both challenges and opportunities, laying the groundwork for a robust conceptual framework.

Moving to the quantitative aspect, a meticulously crafted questionnaire was administered to a diverse pool of bridge asset management representatives across Indonesia. This survey, designed to gauge components within the Theory of Planned Behavior model, meticulously assessed attitudes, subjective norms, and perceived behavioral control. Rigorous statistical analyses, including regression analysis, were then employed to uncover intricate relationships between these factors and the propensity to implement bridge asset management practices effectively.

Moreover, this research methodology extends beyond mere data collection, incorporating a thorough examination of relevant literature, policy documents, and best practices to provide a comprehensive contextual understanding. The strategic utilization of both qualitative and quantitative data not only enriches our insights into the complex dynamics of bridge asset management but also enhances our ability to leverage the Theory of Planned Behavior effectively in improving practices within this critical domain.

The target respondents for this study are bridge asset managers in Indonesia, spread across several directorates and regions. There are 14 sub-directorates in the central office and 33 managers in regional offices directly involved in bridge asset management. Among these numbers, there are also several experienced former managers who are expected to participate in this study, given the limited number of respondents. Considering the limited sample size may affect the statistical outcomes of the research, it is also important to conduct the interview before and after the questionnaire development to vali-date whether the actual condition fits with the research output.

Given the limited pool of bridge asset managers, a purposive sampling strategy was adopted, ensuring the selection of respondents based on their relevance and suitability to contribute meaningfully to the study. The questionnaire was distributed online through a dedicated social network group, yielding a robust response from 65 participants across central and provincial offices. Subsequent data analysis, employing multiple regression analysis and Quantitative Comparative Analysis (QCA), unveiled nuanced correlation values among variables and shed light on distinct patterns across different groups, enriching our understanding of the intricate interplay of factors influencing bridge asset management practices in Indonesia.

Data was subsequently analyzed using Multiple Regression Analysis and Quantitative Comparative Analysis (QCA) to determine correlation values among the variables. Multiple Regression Analysis was utilized to quantify the relationships between a de-pendent variable (Y) and multiple independent variables (X1, X2, X3… Xn). The objective was to comprehend how these independent variables collectively influence the dependent variable [13]. Meanwhile, QCA was applied due to the limited sample size, aiming to elucidate relationships among specific groups, where the outcomes might differ from one group to another [2]. It is concluded that, the use of Multiple Regression Analysis to quantify relationships between dependent and independent variables collectively, alongside Quantitative Comparative Analysis (QCA) for evaluating relationships among specific groups, given the constraints of a limited sample size.

3.1.2 Procedures for Data Preparation and Implementation of LCC

This study compares the LCC analysis results using the iBMS application on several simply supported bridge types made of concrete. Bridge condition data were collected directly from the field by conducting detailed visual surveys on six selected bridges located in East Java Province, Indonesia. This location was chosen due to its favorable inspection track record, aiming to provide a low percentage error between the current inspection results and those from previous years. The focus of this study is on bridge girder structures. Subsequently, visual inspection findings were summarized in a report, including sketches of damage observed on the reviewed elements.

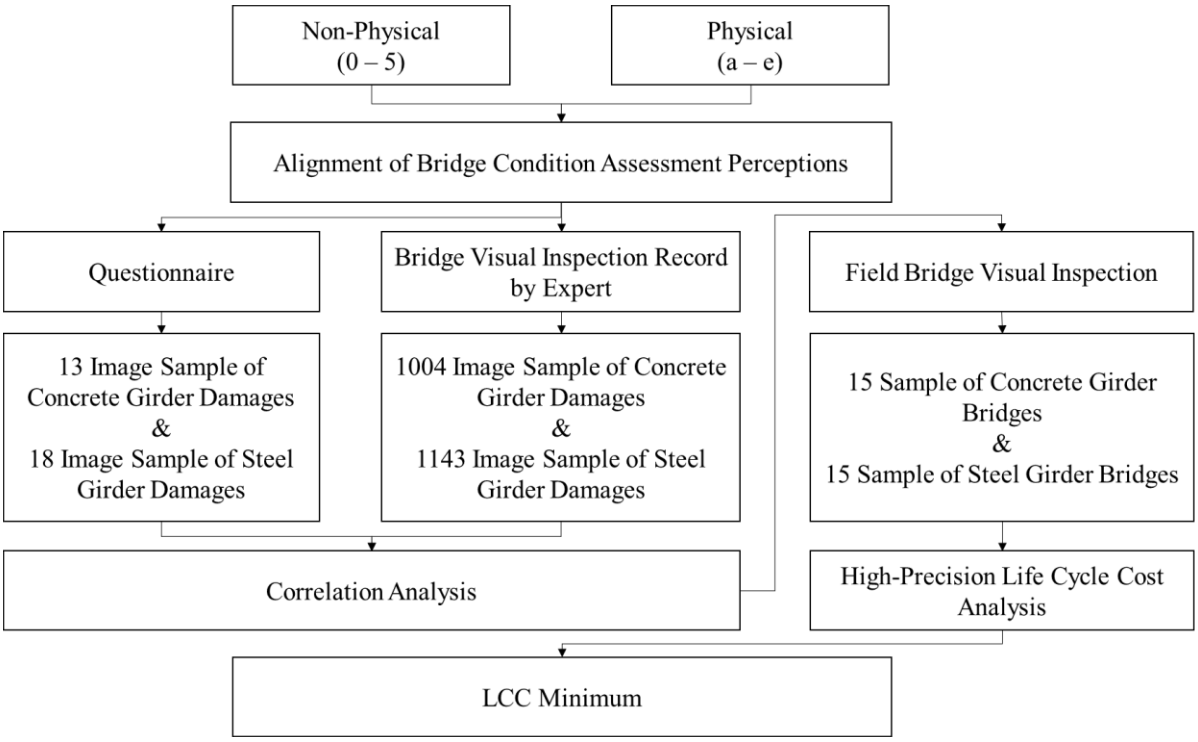


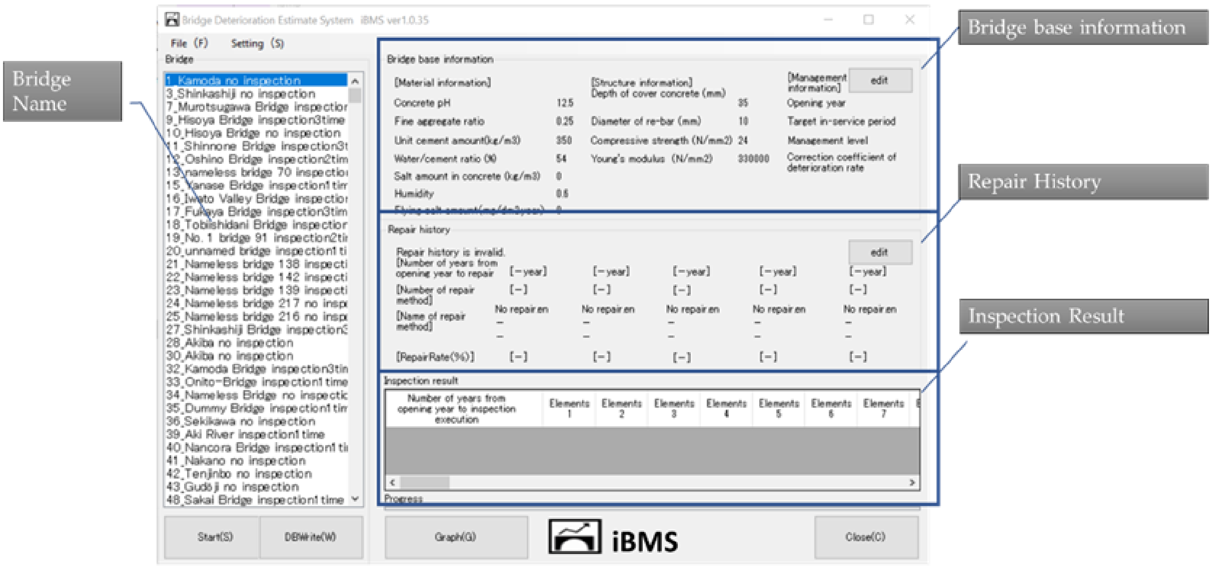
Figure 3-1. Method of aligning perceptions.

Data collection for aligning perceptions of condition assessment is necessary, especially considering the iBMS application used to calculate High-Precision LCCA using criteria in the Japanese guidelines (a–e), which differ from those in Indonesia (0–5). Further-more, this alignment process is conducted using two methods: questionnaire surveys and assessment of visual inspection results of bridges in Japan, employing correlation analysis as depicted in Figure 3-1.

According to Xiangtong W. et al. (2024), Life Cycle Cost (LCC) calculations need to be conducted comprehensively, including the initial construction cost, maintenance costs, and failure costs over the bridge's service life [33]. The LCC aims to minimize costs while ensuring performance and safety. In this study, maintenance costs will be one of the results compared across models based on the visual inspection condition assessments.

The selected bridge will then be assessed using three different condition assessment methods: the Indonesian bridge inspection guidelines, the Japanese inspection guidelines, and the converted assessment results from the perception alignment between Indonesian and Japanese inspectors. By comparing these three methods, we aim to determine which assessment method provides the most optimal LCC value.

The HP-LCCA process using the iBMS application involves preparing several general data sets such as a bridge information base comprising reinforcing bar diameter, concrete strength, concrete cover, and quality information of other structural elements. Additionally, bridge inventory data such as year of service, bridge length, type of structural elements, bridge location, and visual inspection results are necessary, as can be seen in Figure 3-2. Therefore, visual inspections of bridge conditions are conducted in this study to provide a detailed overview of actual field damages. These inspections involve creating reports with sketches to facilitate accurate documentation of damage locations.



1_Kamoda no inspection
3_Shinkashiji no inspection
7_Murotsugawa Bridge inspectior
9_Hisoya Bridge inspection3time
10_Hisoya Bridge no inspection
11_Shinnone Bridge inspection3t
12_Oshino Bridge inspection2tim
13_nameless bridge 70 inspectio
15_Yanase Bridge inspection1 tir
16_Iwato Valley Bridge inspectior
17_Fukaya Bridge inspection3tim
18_Tobishidani Bridge inspectior
19_No. 1 bridge 91 inspection2ti
20_unnamed bridge inspection1 ti
21_Nameless bridge 138 inspecti
22_Nameless bridge 142 inspecti
23_Nameless bridge 139 inspecti
24_Nameless bridge 217 no insp
25_Nameless bridge 216 no insp
27_Shinkashiji Bridge inspection
28_Akiba no inspection
30_Akiba no inspection
32_Kamoda Bridge inspection3tin
33_Onito-Bridge inspection1 time
34_Nameless Bridge no inspectic
35_Dummy Bridge inspection1 tir
36_Sekikawa no inspection
39_Aki River inspection1 time
40_Nancora Bridge inspection1 ti
41_Nakano no inspection
42_Tenjinbo no inspection
43_Gudōji no inspection
48_Sakai Bridge inspection1 time

Bridge base information

[Material information]		[Structure information]		[Management information]
Concrete pH	12.5	Depth of cover concrete (mm)	35	Opening year
Fine aggregate ratio	0.25	Diameter of re-bar (mm)	10	Target in-service period
Unit cement amount(kg/m3)	350	Compressive strength (N/mm2)	24	Management level
Water/cement ratio (%)	54	Young's modulus (N/mm2)	330000	Correction coefficient of deterioration rate
Salt amount in concrete (kg/m3)	0			
Humidity	0.6			
Flying salt amount(mg/dm2/year)	0			

Repair history

Repair history is invalid.

[Number of years from opening year to repair	[−year]	[−year]	[−year]	[−year]	[−year]
[Number of repair method]	[−]	[−]	[−]	[−]	[−]
[Name of repair method]	No repair en − −	No repair en − −	No repair en − −	No repair en − −	No repair en − −
[RepairRate(%)]	[−]	[−]	[−]	[−]	[−]

Inspection result

Number of years from opening year to inspection execution	Elements 1	Elements 2	Elements 3	Elements 4	Elements 5	Elements 6	Elements 7

Figure 3-2. iBMS application for HP-LCCA calculation

In the visual inspection of bridges, two assessment guidelines were employed: the Japanese and Indonesian evaluation models, as depicted in Table 3-1 for non-physical assessment and Table 3-2 for physical assessment. These methods share a similar approach but differ in their assessment models. Japan utilizes a physical model approach, focusing on specific types of damages affecting each structural element individually. In contrast, Indonesia uses a non-physical assessment that sums up five criteria: type of damage, severity of damage, damaged area, element function, and the significance of the damaged element's impact on other elements. The condition of the non-physical element is assessed by taking the worst condition among the structural elements being evaluated.

Table 3-1. Bridge visual condition score in Indonesia [34].

Indonesian Condition Score (Non-Physical Assessment for Each Element)	
0	No defect
1	Minor defect
2	Moderate defect
3	Major defect
4	Critical defect
5	Collapsed

Table 3-2. Bridge visual condition score in Japan [32].

Japanese Condition Score (Physical Assessment for Each Defect)	
a	No defect
b	Minor defect depth and minor defect area
c	Minor defect depth and major defect area
d	Major defect depth and minor defected area
e	Major defect depth and major defected area

Furthermore, as illustrated in Tables 3-1 and 3-2, there are differences in the types of treatments for each damage severity level. This condition necessitates researchers to align the final values so that they can serve as references in the LCCA process using the iBMS application, as iBMS currently only processes physical condition values based on the Japanese assessment guidelines.

Infrastructure managers typically use visual field surveys and interpret inspection reports to predict future structure states and plan maintenance [35]. According to Poli Francesca et al. (2023), regular visual inspections of bridges are subject to uncertainty due to the subjective nature of defect grading based on the inspectors' experience [36]. It also reveals that inspection reports are often overly pessimistic about structural damage, potentially leading to unnecessary rehabilitation interventions [37]. From the aforementioned references, it can be concluded that visual inspections still carry the potential for misinformation due to differences in inspectors' skill levels and errors in condition scoring, resulting in inefficient maintenance interventions.

To bridge the differences in assessment methods, a perception alignment process was conducted through a survey using a questionnaire. This questionnaire was distributed to inspectors from Indonesia and Japan. It contained 13 questions related to photographs of concrete girder and 18 questions of steel girder bridge damage. The assessments were conducted visually in accordance with the inspection guidelines used in both Indonesia and

Japan. Each photograph was explained as objectively as possible, based on actual field conditions, to ensure that each inspector could make accurate assessments based on the provided images and descriptions. The reassessment results were then processed using simple statistical analysis to align them with the condition assessment results obtained using the Japanese method.

Additionally, a condition assessment was also conducted on sample data from bridge condition inspections in Japan, which were evaluated using the Indonesian bridge inspection guidelines. The sample size was determined based on the scope limitations of the study, focusing on concrete and steel girder bridges with damages such as cracks, delamination, spalling, exposed rebar, coatings, and corrosion. This perception alignment serves as the basis for conducting LCCA, where the application utilized has specialized algorithms tailored for condition assessments in Japan.

Based on the two sources mentioned above, it is evident that Japan's bridge condition assessment model is based on the physical condition of structural bridge elements. Each structural element that experiences damage is divided into several segments, allowing for objective evaluation based on the specific damage. This approach results in varying perceptions of condition deterioration across different segments of the same bridge element, depending on the severity of damage observed in each segment.

In contrast, Indonesia employs a hierarchical assessment model that considers the impact of damage to one structural element on other structural elements. Additionally, the condition assessment is based on the most severe damage among the structural elements, by comparing the condition ratings of different elements. Based on this approach, the condition assessment model used in Indonesia is assumed to be non-physical.

To ensure that bridge condition assessment aligns with actual field conditions, both physical and non-physical assessment models heavily depend on the ability of bridge inspectors to objectively evaluate the damage. Structural elements that play a crucial role in supporting the load passing over the bridge are visually assessed based on the inspectors' expertise. However, this also introduces the possibility of assessment errors, which could lead to mistakes in planning the necessary bridge maintenance.

The determination of the level of importance in maintaining structural elements of the bridge is carried out by expert engineers who provide objective assessments. They are responsible for providing accurate recommendations for appropriate field interventions. Expert engineers are expected to interpret the damage to each structural element, estimate the volume and severity of the damage, and record the location of the damage in detail according to the applicable guidelines. Additionally, they should understand the primary function of the structural elements, potential interactions with other damaged structural elements, previous maintenance interventions, and factors such as traffic load, corrosion causes, and the approximate location of the bridge from the sea.

CHAPTER 4
THE INTENTION OF BRIDGE ASSET MANAGEMENT IMPLEMENTATION

4.1 Motivation for Investigating Managerial Intentions

As a developing nation, Indonesia is currently undergoing a period of swift infrastructure development, with a particular emphasis on prioritizing elements such as roads and bridges. These endeavors reflect the government's commitment to enhancing logistical efficiency across different regions. With a large number of road and bridge assets across Indonesia, there is a need for asset manager to provide precise information on the number of assets, condition, and maintenance plans. The abundance of assets is accompanied by a myriad of challenges, posing a significant concern for researchers striving to devise pertinent solutions. The current nationwide adoption of the road and bridge data management system by the Indonesian government remains underutilized, particularly in the context of decision-making, with a noticeable gap in the effective utilization of bridge-related data. This raises important questions, which this study answers, regarding the factors that contribute to the suboptimal implementation of bridge asset management in Indonesia. Moreover, this research aims to elucidate the motivations underlying the actions of asset managers in Indonesia who have not demonstrated their intention in executing bridge asset management.

The global adoption of bridge asset management practices has surged, with numerous bridge agencies transitioning to sophisticated Bridge Management Systems (BMS) [38]. The overarching goal behind implementing a BMS is to holistically optimize costs throughout a bridge's lifespan, all while prioritizing user safety and safeguarding the as-set value of crucial infrastructure [39]. This objective is realized through a meticulous process of data-driven decision-making, leveraging insights gleaned from the condition and performance metrics of bridges [40]. Thus, the widespread embrace of Bridge Management Systems (BMS) for bridge asset management is not only evident but also underscored by their pivotal role in cost optimization, user safety assurance, and the preservation of infra-structure asset value, all driven by informed decisions rooted in bridge condition and performance data.

Within the realm of successful Bridge Asset Management implementation, the government agencies astutely recognize the hurdles embedded in this intricate process, particularly when sculpting an asset management decision-making framework around strategic objectives [41]. Government agencies are grapple with the intricate challenge of catering to diverse stakeholders, each harboring strong opinions shaped by their unique perspectives on asset management. The perpetual focus on short-term budgets further complicates matters, impeding the fulfillment of comprehensive capital investment planning prerequisites crucial for the efficacy of asset management. Furthermore, in the face of mounting pressure to achieve more with finite resources—be it technological, financial, or staff-related tangible constraint emerges in meeting the demands inherent in a robust Bridge Asset Management system.

The main aim of bridge management is to find the best strategy that keeps bridges safe while also saving money [42]. This means carefully balancing safety and cost throughout the process. To make Bridge Management System (BMS) deployment more effective, systems and technology can enhance the efficiency and effectiveness of bridge management by providing reliable and objective information [43, 44]. This system helps managers make better decisions by considering different factors. Additionally, advanced technologies like Building Information Modeling (BIM) and Unmanned Aerial Systems (UAS) can improve bridge inspections and management, especially with BMS [45, 46, 47, 48]. These technologies play a crucial role in making BMS implementation more efficient, particularly in tasks like inspections and data management. Overall, effective asset management relies on supportive systems and technologies that simplify decision-making for managers.

The successful implementation of a Bridge Management System (BMS) is not merely a technological exercise but a multifaceted organizational transformation that requires a coordinated approach across strategic, technical, and institutional dimensions. Literature consistently underscores that effective deployment hinges on the presence of a robust change management strategy that guides the transition from traditional asset management practices toward data-driven, systematized decision-making. Such a strategy must be underpinned by clear objectives, effective communication structures, comprehensive training initiatives, and active stakeholder engagement. These elements not only ensure the system's functional adoption but also enhance its legitimacy and acceptance within the organizational culture.

At the same time, decision-making processes in bridge asset management are often hindered by structural limitations—such as incomplete data, inconsistent condition assessments, and the absence of an integrated national database—which constrains the ability of asset managers to plan, prioritize, and allocate resources effectively. Addressing these constraints demands the development of a detailed deployment framework that is tailored to organizational contexts, supported by adequate financial, human, and technological resources, and designed to ensure the system's long-term sustainability. Integration of the BMS into existing workflows further amplifies its effectiveness by improving data interoperability, streamlining operational processes, and facilitating more agile and informed decision-making.

Moreover, BMS implementation is not a one-time effort but an evolving process that requires continuous performance evaluation, periodic system updates, and adaptive management strategies. The dynamic nature of bridge infrastructure, coupled with advancements in technology and changing policy environments, necessitates ongoing improvement and learning. Promoting a culture of collaboration, knowledge sharing, and professional development among asset management personnel strengthens institutional capacity and ensures that the BMS evolves in tandem with emerging challenges and opportunities.

However, the broader landscape of public sector asset management presents persistent challenges that must be addressed alongside system deployment. Inefficient maintenance practices, inadequate governance mechanisms, resource constraints, and the absence of clear technology implementation guidelines continue to undermine the effectiveness of asset management programs. These issues underscore the importance of adopting a holistic perspective that integrates technical solutions with institutional reforms, policy alignment, and organizational capacity-building.

In synthesis, the literature reveals that effective BMS implementation is achieved through the intersection of four critical dimensions: organizational transformation, which establishes the structural and cultural foundation for adoption; strategic planning and resource allocation, which ensure operational readiness and sustainability; integration and continuous improvement, which maintain system relevance and performance over time; and institutional adaptation, which addresses systemic challenges in public asset governance. The interplay of these dimensions provides a comprehensive pathway for bridging the gap between technical capability and managerial decision-making, ultimately enabling more efficient, transparent, and sustainable management of bridge infrastructure assets.

Previous research has extensively discussed the successful implementation of bridge asset management using various methods, but it has not been specific enough to address asset management practitioners. Only a few references cited underscore the significant influence of asset managers in enhancing asset management practices. Nonetheless, the variability in individual asset managers' comprehension of the system has impeded the optimal effectiveness of bridge asset management. This study endeavors to rectify this issue by offering insights into the requisite characteristics of an ideal asset manager essential for the successful implementation of bridge asset management.

Despite extensive research on bridge asset management practices, a significant gap remains in the existing body of knowledge—specifically, the limited attention given to understanding asset managers' preferences and decision-making perspectives in the implementation process. This underexplored area highlights the critical need for comprehensive investigations that examine the diverse and interconnected factors influencing successful adoption and execution. Addressing this gap is essential, as it opens new avenues for scholarly inquiry and contributes to a deeper theoretical and practical understanding of how managerial preferences shape the effectiveness of bridge asset management strategies.

4.1.1 Theoretical Foundation of the Analytical Framework

Based on an extensive review of the relevant literature, it is evident that the implementation of bridge asset management does not always proceed as planned. This review identifies several recurrent factors reported across prior studies that may influence bridge asset managers' willingness to engage in asset management. These factors include limited budget allocation, insufficiently validated and low-quality bridge condition data, policies that are not fully supportive or effectively enforced, shortages of human resources and appropriate tools, and the underutilization of bridge management systems. Collectively, these issues constitute major barriers to successful bridge asset management implementation. However, it remains necessary to determine the extent to which each factor affects asset managers' intention to manage bridge assets effectively. Accordingly, these factors are incorporated into a conceptual research model grounded in the Theory of Planned Behavior (TPB), where they are hypothesized to shape asset managers' attitudes, subjective norms, and perceived behavioral control, as illustrated in Figure 4-1.

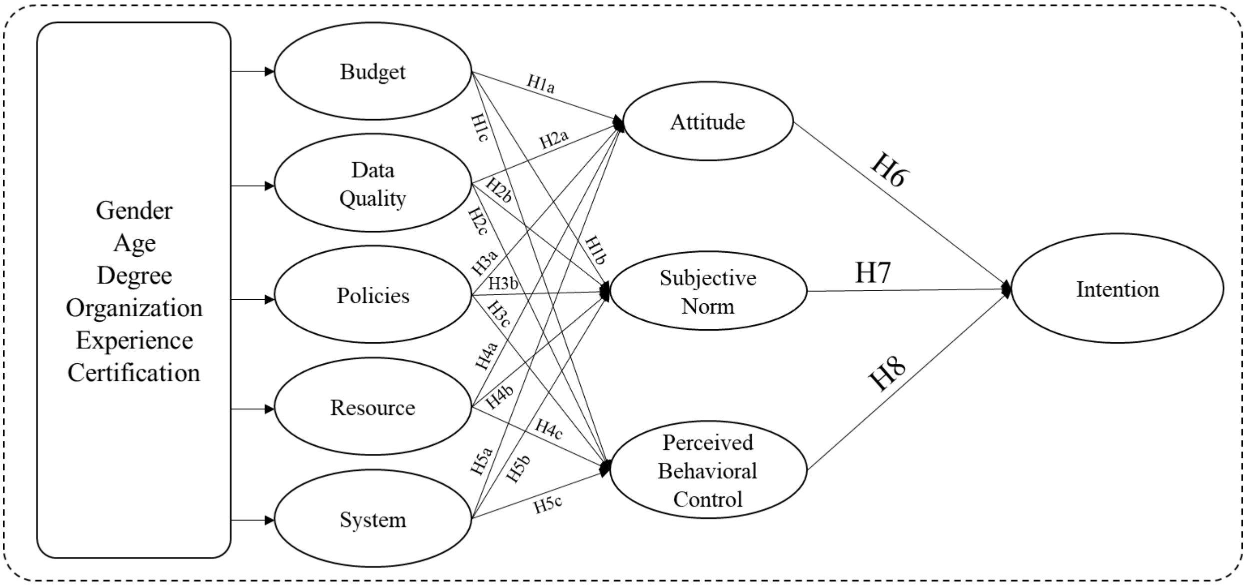


Figure 4-1. Conceptual Model

These five factors influencing attitude, subjective norms, and perceived behavioral control of bridge asset managers and their inclination to engage in bridge asset management have been identified. These factors serve as the foundation for developing a model that elucidates the influence of a bridge asset manager's intent. The first factor for measurement is the budget availability for bridge asset management. The second is data quality, followed by the impact of policies, the availability of resources (both human and equipment), and the effectiveness of the bridge asset management system used. The forth-coming section details each of the five hypotheses presented in the literature review and hypothesis development chapter.

The identified variables are used to formulate a research hypothesis, drawing on literature from similar research models. Adjustments are made in this study to articulate the hypotheses discussed earlier. Consequently, the research questionnaire is expected to effectively test the validity and reliability of several questions. The relationship between variables and hypotheses is depicted as positive in Table 1 and will be supported by questions derived from the literature review, adjusted to fit the research objectives, as shown in Table 4-1.

Table 4-1. Hypothesis

Variable	Hypothesis	Source
Budget	(H1a) Budget allocation has a positive effect on attitude. (H1b) Budget allocation has a positive effect on subjective norms. (H1c) Budget allocation has a positive effect on perceived behavioral control	Modified from [49,50,51,52,53]
Data Quality	(H2a) Data quality has a positive effect on attitude. (H2b) Data quality has a positive effect on subjective norms. (H2c) Data quality has a positive effect on perceived behavioral control	Modified from [54,55,56,57,52]
Policies	(H3a) Policies have a positive effect on attitude. (H3b) Policies have a positive effect on subjective norms. (H3c) Policies have a positive effect on perceived behavioral control	Modified from [58,59,60,61,52]
Resource	(H4a) The resource has a positive effect on attitude. (H4b) The resources have a positive effect on subjective norms. (H4c) The resource has a positive effect on perceived behavioral control	Modified from [62,63,64,65,52]
System	(H5a) The system has a positive effect on attitude. (H5b) The system has a positive effect on subjective norms. (H5c) The system has a positive effect on perceived behavioral control	Modified from [66,67,68,69,52]
Attitude	(H6) Attitude has a positive effect on Intention	Modified from [38,51,52]
Subjective norms	(H7) Subjective norms have a positive effect on Intention	Modified from [52,69,70,71]
Perceived behavioral control	(H8) Perceived behavioral control has a positive effect on Intention	Modified from [52,69,70,71]

In this study, five main variables (Budget, Data Quality, Policies, Resources, System) serve as predictors, with each having three measurement items that represent their relationship with the dependent variables. There are three dependent variables: Attitude, Subjective Norms, and Perceived Behavioral Control. Each of these dependent variables also includes several modified measurement items derived from relevant research literature.

4.2 Empirical Findings on Managerial Intentions

4.2.1 Demographic Profile and Survey Outcomes

The data collection process for this study employed a questionnaire method, which was meticulously designed based on the theoretical framework aligned with the Theory of Planned Behavior. The questionnaire was specifically tailored for asset managers directly involved in the management of bridges within the jurisdiction of national roads. Each factor influencing Attitude, Subjective Norm, and Perceived Behavioral Control served as a measuring tool to predict a manager's inclination toward bridge asset management. The initial segment of the questionnaire encompassed demographic information about the respondents, including gender, age, education, organizational affiliation, experience, and certification ownership. The second section consisted of various statements derived from Attitude, Subjective Norm, Perceived Behavioral Control, and Intention. These statements were formulated to gauge the intentions of asset managers in effectively administering bridge asset management.

Table 4-2. Respondent demographics

Variable	Category	Frequency	Percentage (%)
Gender	Male	57	87.69
	Female	8	12.31
Age	21-40	41	63.07
	41-60	21	32.31
	>60	3	4.62
Education	Undergraduate	27	41.54
	Graduate	38	58.46
Organization	National Road Implementation Agency	29	44.62
	Directorate	36	55.38
Experience	< 10 Year	34	52.31
	≥ 10 Year	31	47.69
Certification	Certified	35	53.85
	Not Certified	30	46.15

Table 4-2 presents demographic information for the study's 65 participants. The majority were male (87.69%), with 57 males and 8 females. Regarding age, 63.07% were between 21 and 40 years old, while 32.31% were aged 40 to 60, mainly senior managers, and 4.62% were 60 or older. Educational backgrounds varied: 41.54% held undergraduate degrees, and 55.38% had graduate degrees. In terms of affiliation, 44.62% were with the National Road Implementation Agency, and 55.38% were with the Directorate. Work experience was split, with 52.31% having less than 10 years and 47.69% over 10 years. Additionally, 53.85% held certifications, while 46.15% did not.

In this questionnaire, several questions are presented using a Likert scale measurement (ranging from Strongly Disagree to Strongly Agree) with values ranging from 1 to 5. The questionnaire comprises statements depicting the relationships between factors and Attitude, Subjective Norms, as well as Perceived Behavioral Control. The aim is to capture the intentions of bridge asset managers concerning achieving optimal outcomes in bridge asset management. Responses from participants to the statements presented in the questionnaire are illustrated in Table 4-3.

Table 4-3. Questionnaire response

Variable	Measurement Items	Mean	Sd
Budget (BG)	• (BG-ATT) I need to allocate a budget for the bridge asset management system. The availability of funds will impact my attitude toward bridge asset management implementation.	4.54	0.588
	• (BG-SN) I prefer to allocate a budget for the implementation of a bridge asset management system because the availability of a budget will affect my work environment and behavior to carry out bridge asset management.	4.34	0.713
	• (BG-PBC) I believe the budget allocation for the bridge asset management system will improve the quality of bridge planning and programming results because the availability of the budget will affect my confidence in implementing bridge asset management.	4.46	0.686
Data Quality (DQ)	• (DQ-ATT) I want to improve the data quality for better implementation of the bridge asset management system because good data quality will affect my attitude toward implementing bridge asset management.	4.82	0.429

Variable	Measurement Items	Mean	Sd
	• (DQ-SN) I prefer to improve data quality for use in the bridge asset management system because good data quality will affect my work environment and behavior in carrying out bridge asset management.	4.74	0.476
	• (DQ-PBC) I believe that the accuracy of the data collected has a direct impact on the effectiveness of the implementation of bridge asset management because good data quality will affect my confidence in implementing bridge asset management.	4.71	0.491
Policies (PC)	• (PC-ATT) I want to update the policy for better implementation of the bridge asset management system because proper and appropriate policy will affect my attitude toward implementing bridge asset management.	4.52	0.615
	• (PC-SN) I prefer to update the policy for better implementation of the bridge asset management system because the right and appropriate policy will affect my work environment and behavior in carrying out bridge asset management.	4.38	0.7
	• (PC-PBC) I believe that the right policy framework will increase the effectiveness of the implementation of Bridge Asset Management because the right and appropriate policies will affect my confidence in implementing bridge asset management.	4.52	0.562
Resource (RC)	• (RC-ATT) I want to allocate staff and equipment to implement the bridge asset management system because the availability of resources will affect my attitude toward carrying out bridge asset management.	4.66	0.538
	• (RC-SN) I prefer to allocate staff and equipment to support the implementation of the bridge asset management system because the availability of human resources and equipment will affect my work environment and behavior to carry out bridge asset management.	4.45	0.638
	• (RC-PBC) I believe that defining clear roles and responsibilities for human resources and the availability of tools will improve the implementation of bridge asset management because the availability of human resources and equipment will affect my confidence in carrying out bridge asset management.	4.62	0.604
System (SY)	• (SY-ATT) I want to improve the capabilities of the existing system for better implementation of bridge asset management. The available system will influence my attitude toward implementing bridge asset management.	4.66	0.508
	• (SY-SN) I prefer to update the system for better implementation of bridge asset management because the system that suits my needs will influence my work environment and behavior to carry out bridge asset management.	4.46	0.663
	• (SY-PBC) I believe that a system that fits the needs is very important for the accuracy and effectiveness of bridge asset management because a system that fits the needs will affect my ability to carry out the bridge.	4.57	0.558
Attitude (ATT)	• (ATT1) I would like to implement Bridge Asset Management to improve the durability and longevity of infrastructure.	4.62	0.629

Variable	Measurement Items	Mean	Sd
	• (ATT2) Implementing Bridge Asset Management would enhance cost-effectiveness in maintenance and repairs, which is something I'm interested in.	4.68	0.562
Subjective Norms (SN)	• (SN1) I prefer to be supportive in implementing Bridge Asset Management practices as recommended by my colleagues.	3.8	1.064
	• (SN2) I prefer to participate in the implementation of Bridge Asset Management practices as recommended by my superior.	3.88	0.91
	• (SN3) I prefer to support the implementation of Bridge Asset Management as directed by my organization.	4.23	0.786
Perceived Behavioral Control (PBC)	• (PBC1) I believe that putting time and resources will improve the implementation of Bridge Asset Management result.	4.32	0.664
	• (PBC2) I believe that proactive steps are needed to support and contribute to the implementation of Bridge Asset Management	4.51	0.534
	• (PBC3) I believe in the successful implementation of Bridge Asset Management, and I will recommend it to my colleagues and peers	4.45	0.613
Intention	• (INT1) I have the intention to implement the Bridge Asset Management.	4.62	0.521
	• (INT2) I have the intention to recommend Bridge Asset Management to my colleagues, superiors, and organization.	4.51	0.589
	• (INT3) I plan to allocate time and resources to ensure the effective implementation of Bridge Asset Management.	4.43	0.585
	• (INT4) I have the intention to be proactive, support, and contribute to the implementation of Bridge Asset Management.	4.49	0.562

Table 4-3 reveals that respondents generally show agreement with the questionnaire statements, as reflected in average response values ranging from 3.8 to 4.82. Particularly noteworthy is the statement concerning the impact of data quality on attitude, which receives the highest average score and the lowest standard deviation. This suggests a consistent trend among respondents toward prioritizing data quality improvement, indicating a collective willingness to enhance data quality in support of bridge asset management.

To optimize the analysis given the limited number of respondents holding managerial positions in bridge asset management, two analytical approaches will be employed: Multiple Regression Analysis and Quantitative Comparative Analysis (QCA). Multiple Regression Analysis, conducted using SPSS software, will examine relationships between predictors and the dependent variable. This will be demonstrated through Standardized Coefficients Beta values, where values <0.05 indicate statistical significance. The goal is to understand the extent to which each predictor contributes to the dependent variable. Concurrently, QCA will be performed using fsQCA software to identify the data configurations most supportive of managerial intentions. This analysis will explore various combinations of factors and variables, providing insights into the configurations aligning best with managerial intentions. Utilizing both methodologies will enrich the analytical process, considering nuanced aspects of the data and ensuring a robust exploration of potential relationships.

4.2.2 Regression Analysis of Influencing Variables

The Multiple Regression analysis results are presented in detail in Table 4-4, showing the relationship between various predictors and dependent variables in bridge asset management. Budget emerges as the primary determinant for Attitude, showing a moder-ate positive effect. Policies are the most significant determinant for the subjective norm, while Budget has a weak positive effect. Perceived Behavioral Control is influenced by Budget, Data Quality, and Resource, showing moderately significant positive effects. Finally, Perceived Behavioral Control has the highest impact on Intention, followed by Attitude, albeit weakly, while Subjective Norm shows a weak and non-significant relationship with Intention.

Table 4-4. Multiple Regression Analysis results

Predictors → Dependent Variable	Standardized Coefficients Beta (β*)	Sig. (P)	Hypothesis
Budget → Attitude	0.382	<0.001	H1a → supported
Data Quality → Attitude	0.252	0.004	H2a → supported
Policies → Attitude	0.267	0.003	H3a → supported
Resource → Attitude	0.087	0.381	H4a → not supported
System → Attitude	0.105	0.376	H5a → not supported
Budget → Subjective Norm	0.138	0.021	H1b → not supported
Data Quality → Subjective Norm	0.026	0.676	H2b → not supported
Policies → Subjective Norm	0.408	<0.001	H3b → supported
Resource → Subjective Norm	0.073	<0.001	H4b → supported
System → Subjective Norm	0.091	0.007	H5b → not supported

Predictors → Dependent Variable	Standardized Coefficients Beta (β*)	Sig. (P)	Hypothesis
Budget → Perceived Behavioral Control	0.258	<0.001	H1c → supported
Data Quality → Perceived Behavioral Control	0.264	<0.001	H2c → supported
Policies → Perceived Behavioral Control	0.005	0.944	H3c → not supported
Resource → Perceived Behavioral Control	0.276	0.001	H4c → supported
System → Perceived Behavioral Control	0.274	0.008	H5c → not supported
Attitude → Intention	0.219	0.071	H6 → not supported
Subjective Norm → Intention	-0.065	0.536	H7 → not supported
Perceived Behavioral Control → Intention	0.574	<0.001	H8 → supported

Figure 4 reveals the relationship between various predictors and the dependent variable, Attitude. Budget emerges as the primary determinant for bridge asset managers, showing a moderate positive effect on Attitude. Data and Policies also demonstrate statistically significant positive effects on Attitude, albeit weaker than Budget. Conversely, Resource and System exhibit non-significant effects on Attitude, suggesting a weak and in-conclusive relationship.

In determining the subjective norm of a bridge asset manager in Figure 4-2, Policies emerge as the most significant determinant, showing a strong positive relationship. Resources also have a significant positive effect, though moderately weaker than Policies. Budget and System demonstrate statistically significant but weak positive effects on the subjective norm. However, Data has a non-significant and very weak influence on subjective norms.

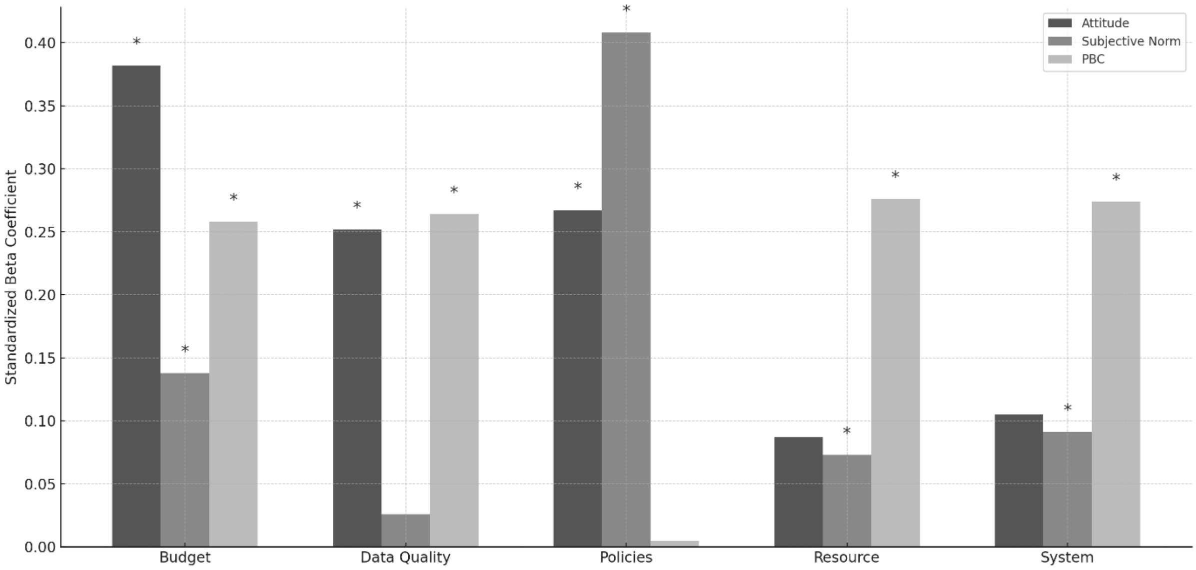


Figure 4-2. Predictors influencing Dependent Variables

According to Figure 4-2, Perceived Behavioral Control is influenced by three predictors: Budget, Data Quality, and Resource, show moderately significant positive effects on Perceived Behavioral Control, indicating that increases in these factors are associated with increased control perception. The System also demonstrates a moderately strong positive effect on Perceived Behavioral Control. However, Policies have a non-significant and very weak influence, suggesting they do not significantly affect Perceived Behavioral Control.

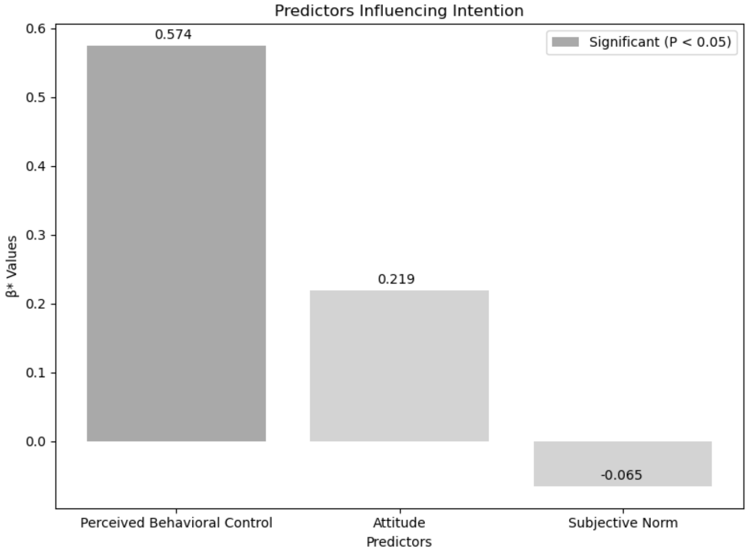


Figure 4-3. Predictors influencing Intention

Based on the analysis in Figure 4-3, the predictor with the highest impact on Intention is Perceived Behavioral Control, showing a robust positive relationship with Intention. Attitude demonstrates a non-significant but weakly positive relationship with Intention, indicating a slight potential contribution. Subjective Norm, however, shows a non-significant and weak negative influence on Intention, suggesting a weak and non-significant relationship.

4.2.3 Comparative Findings from QCA

To determine the most optimal model configuration that yields the highest values for coverage and consistency, calculations were conducted using the fsQCA application with truth table analysis on the parsimonious and intermediate solutions. In this computation, Intention serves as the output variable incorporating budget, data quality, policies, resources, and system as factors. Additionally, attitude, subjective norm, and perceived behavioral control are included as causal conditions, with the results presented in Table 4-5. According to [72,73], the categorization of causal conditions into core or peripheral configurations is based on the parsimonious solution and intermediate solution: core conditions are those present in both parsimonious and intermediate solutions, while peripheral conditions are eliminated in the parsimonious solution and only appear in the intermediate solution. Thus, this approach defines causal coreness in terms of the strength of evidence relative to the outcome, rather than connectedness to other configurational elements.

According to the results of the fsQCA calculations presented in Table 4-5, the core conditions that emerge are data quality and system, along with Attitude, Subjective Norm, and Perceived Behavioral Control, as indicated in the solution column. This occurrence is due to these condition configurations appearing in both parsimonious and intermediate solutions. Based on Table 4-5, two dominant patterns emerge for solutions that an asset manager can employ in bridge asset management, namely solutions three and fifteen. The third solution exhibits the highest coverage value at 71.6%, coupled with a consistency value of 0.937. This finding indicates that Budget, Data, Resources, and Systems positively influence the Intention of a bridge asset manager, with Data and System serving as core conditions. Additionally, both Attitude and Perceived Behavioral Control contribute to this positive influence. Another notable solution is found in the 15th configuration, which has a coverage value of 57.6% and a consistency value of 0.929. In this five-tenth configuration, Budget, Policies, Resources, and System exhibit positive influences, along with Attitude, Subjective Norm, and Perceived Behavioral Control, on the Intention of a bridge asset manager.

Table 4-5. All factors towards intention

Config.	**Solution**																	
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**
Budget	x		o		x	x	x	x	x	x	x	o	x	o	o	x	o	x
Data	**O**	**O**	**O**	**O**	**O**	**X**	**X**	**X**	**X**	**O**	**O**			**O**		**X**	**X**	**O**
Policies		o		x	x	x	x	o	x	o	o	x	o	o	o	x	o	o
Resources	o	o	o	x		x	x		x	o	o	o	o		o	x	o	x
System	**O**	**O**	**O**	**X**	**X**	**X**		**X**	**X**	**O**	**O**	**X**	**O**	**O**	**O**	**O**	**X**	**O**
Attitude	**O**	**O**	**O**	**X**	**X**	**O**	**X**	**X**	**O**	**X**	**O**	**O**	**O**	**O**	**O**	**X**	**X**	**O**
Subj. Norm				**X**	**X**		**O**	**O**	**O**	**X**	**X**	**O**	**O**	**O**	**O**	**X**	**O**	**O**
PBC	**X**	**X**	**O**	**X**	**X**	**X**	**X**	**X**				**X**	**X**	**X**	**O**	**O**	**O**	**O**
Consistency	0.971	0.961	0.937	0.850	0.849	0.883	0.887	0.908	0.909	0.986	0.964	0.947	0.975	0.977	0.929	0.967	0.995	0.992
Raw Cov.	0.273	0.305	0.716	0.172	0.171	0.175	0.157	0.164	0.161	0.177	0.224	0.193	0.224	0.267	0.576	0.154	0.156	0.186
Unique Cov.	0.001	0.009	0.094	0.011	0.007	0.003	0.007	0.005	0.001	0.004	0.003	0.003	0	0.004	0.001	0.005	0.004	0.004

Note: O = core causal condition (present). o = peripheral causal condition (present). X = core causal condition (absent). x = peripheral causal condition (absent). Blank spaces indicate "do not care".

In the analysis phase using QCA, a more in-depth investigation is also conducted regarding the preferences of a manager in implementing bridge asset management. In this stage, data is categorized into three detailed scopes. Firstly, a comparison is made between Certified Bridge Asset Managers and Non-Certified Bridge Asset Managers. The term "Certified" here refers to asset managers who have obtained certification in the field of bridge expertise. Secondly, a comparison is made between Bridge Asset Managers with less than 10 years of experience and those with more than 10 years of experience. Lastly, a comparison is made between Directorate-level Bridge Asset Managers (central) and Bridge Asset Managers at the National Road Agency (regional). The results of these comparisons aim to identify the factors that tend to influence the intention of a bridge asset manager to effectively implement bridge asset management.

Table 4-6. Certified (a) vs non-certified (b) bridge asset managers

Variable	**Solution**					
	1a	**2a**	**3a**	**1b**	**2b**	**3b**
Attitude	**O**			**O**		
Subjective Norm		**O**			**O**	**X**
Perceived Behavioral Control			**O**		**X**	**O**
Raw coverage	0.904	0.709	0.821	0.884	0.305	0.408
Consistency	0.801	0.843	0.904	0.764	0.834	0.909

Note: O = core causal condition (present). o = peripheral causal condition (present). X = core causal condition (absent). x = peripheral causal condition (absent). Blank spaces indicate "do not care".

Certified bridge asset managers exhibit nearly uniform values for coverage and consistency across each predictor. Specifically, the coverage values for Attitude, Subjective Norm, and Perceived Behavioral Control are 90.5%, 70.9%, and 82.1%, respectively, with corresponding consistency values of 0.801, 0.843, and 0.904, as illustrated in Table 4-6. The model for Certified Asset Managers, developed through the Quine-McCluskey algorithm, highlights robust relationships between key predictor variables (Attitude, Subjective Norm, and Perceived Behavioral Control) and Intention. Conversely, in the model for Non-Certified Asset Managers, it is evident that only Attitude tends to influence Intention, with a coverage value of 88.41% and a consistency value of 0.764. This comparison underscores the nuanced differences in the factors influencing the intention of certified versus non-certified bridge asset managers in the context of bridge asset management.

In Table 4-7, it is evident that managers with more than 10 years of experience show Attitude as the dominant predictor, exerting a remarkably high influence on Intention, supported by a high raw coverage of 93.2% and a consistency level of 0.808. On the other hand, managers with less than 10 years of experience indicate that all three predictor variables—Attitude, Subjective Norm, and Perceived Behavioral Control—play significant roles in predicting Intention. The respective coverage values for these predictors are 85.7%, 67.6%, and 81.4%, each with consistency values above 0.75. This suggests a nuanced relationship between experience level and the influencing factors on the intention of bridge asset managers, emphasizing the varying dynamics within different experience cohorts.

Table 4-7. Experience (a) vs less experience (b) bridge asset managers

Variable	**Solution**					
	1a	**2a**	**3a**	**1b**	**2b**	**3b**
Attitude	**o**			**o**		
Subjective Norm		**o**	**x**		**o**	
Perceived Behavioral Control		**x**	**o**			**o**
Raw coverage	0.932	0.295	0.425	0.857	0.676	0.814
Consistency	0.808	0.787	0.934	0.757	0.758	0.847

Note: O = core causal condition (present). o = peripheral causal condition (present). X = core causal condition (absent). x = peripheral causal condition (absent). Blank spaces indicate "do not care".

As explained in Table 4-8, bridge asset managers at the Directorate (central) level tend to have high values for the predictor's Attitude and Perceived Behavioral Control to Intention. The respective coverage values for these predictors are 90.7% and 83.8%, with consistency values surpassing 0.8.

Table 4-8. Directorate vs National Road Agency bridge asset managers

Variable	**Solution**				
	1a	**2a**	**1b**	**2b**	**3b**
Attitude	**O**		**O**		
Subjective Norm				**O**	**X**
Perceived Behavioral Control		**O**		**X**	**O**
Raw coverage	0.907	0.838	0.881	0.315	0.454
Consistency	0.805	0.87	0.757	0.837	0.921

Note: O = core causal condition (present). o = peripheral causal condition (present). X = core causal condition (absent). x = peripheral causal condition (absent). Blank spaces indicate "do not care".

These findings illustrate significant and consistent relationships with Intention, underscoring their reliability in forecasting this dependent variable. Conversely, bridge asset managers at the National Road Agency (regional) level emphasize the dominance of Attitude as a predictor of Intention, with a coverage value of 88.1% and a consistency value of 0.757. This suggests a nuanced variation in the influential factors on the intention of bridge asset managers based on their organizational roles within the central or regional structure.

Table 4-9. Attitude, Subjective Norm, and PBC towards Intention

Variable	Solution		
	1	**2**	**3**
Attitude	**O**		
Subjective Norm		**O**	
Perceived Behavioral Control			**O**
Raw coverage	0.895	0.699	0.825
Consistency	0.783	0.803	0.872

Note: O = core causal condition (present). o = peripheral causal condition (present). X = core causal condition (absent). x = peripheral causal condition (absent). Blank spaces indicate "do not care".

From the QCA calculations, measurements of the variables Attitude, Subjective Norm, and Perceived Behavioral Control towards Intention were conducted. Table 4-9 observed that Attitude dominates the intention of a bridge asset manager at 89.52%. However, its consistency value is slightly lower compared to Perceived Behavioral Control, with values of 0.783 (below 0.8) for Attitude and 0.872 for Perceived Behavioral Control. On the other hand, Subjective Norm exhibits the lowest coverage value at 69.97%, with a consistency value of 0.803. This condition indicates that the perceived behavioral control of asset managers has a strong influence on their inclination to implement bridge asset management, emphasizing its pivotal role in shaping intention.

4.2.4 Insights from Expert Interviews

Interviews with multiple bridge asset management experts in Indonesia strongly corroborate the findings of the data analysis. Overall, respondents expressed predominantly negative views regarding the current state of bridge asset management, emphasizing substantial shortcomings. Approximately half of the experts (50%) highlighted funding constraints as a major challenge, resulting in insufficient support for essential asset management activities. These funding gaps not only undermine the quality of bridge condition data but also intensify regional disparities in inspection capacity, with expertise disproportionately concentrated in western regions of the country.

Financial constraints loom large in the effective management of bridge assets, with current priorities skewed towards road construction and preservation, leaving bridge asset management underfunded and undervalued. This disparity in funding priorities hampers the implementation of proactive maintenance strategies, leading to a reactive approach that may inflate intervention costs in the long run.

A clear consensus emerged, with approximately 71% of experts emphasizing the urgent need for coherent policies that clearly delineate the responsibilities of bridge asset managers and provide standardized operating procedures. Moreover, given the relatively nascent stage of bridge asset management in Indonesia, comprehensive adaptation efforts are required across all stakeholders, particularly among bridge asset managers themselves.

Another critical issue, identified by approximately 86% of experts, is the scarcity of resources available to bridge asset managers, which results in suboptimal intervention programming and a heavy reliance on central agencies for both human and technical support. This centralized approach not only constrains regional autonomy but also contributes to duplicated efforts and delays in bridge condition validation.

According to approximately 71% of experts, the current programming tool, although pivotal for cost planning and intervention prioritization, remains in an early stage of development, which limits its effectiveness in supporting annual programming decisions. In addition, manual programming using Excel lacks the analytical sophistication required to optimize resource allocation, often leading to disproportionate budget allocations for corrective maintenance at the expense of preventive measures.

Experts observe that this situation limits asset managers to mainly engage in corrective maintenance, where a significant portion of the budget is allocated to bridges classified as severely damaged or critical. In this scenario, the allocation for preventive bridge maintenance is sacrificed for more extensive interventions. Such management practices raise concern among experts as they may lead to inflated bridge intervention costs in the future.

Data quality emerges as a recurring concern among 86% of experts, exacerbated by the absence of certified bridge inspectors and by asset managers' limited understanding of bridge deterioration mechanisms. This deficiency undermines the effectiveness of bridge asset management practices and underscores the urgent need for standardized inspection procedures and robust certification protocols.

To address these multifaceted challenges, experts unanimously advocate for the establishment of guidelines governing bridge asset management needs, encompassing standards for human resources, equipment, systems, and data. Clear leadership directives are deemed essential to ensure coherence and accountability at both central and regional levels, fostering a unified approach towards achieving the goals of the asset management program.

From the experts' perspective, Indonesia faces multiple obstacles to effective bridge asset management implementation, with the most pressing priorities being improvements in data quality and resource capacity. These should be followed by strengthening policies and system robustness to better support implementation. Finally, establishing an appropriate and sustainable budget is necessary to ensure that bridge asset management can be executed effectively and consistently.

4.3 Interpretation of Empirical Findings

The intention of asset managers is influenced by attitude, subjective norms, and perceived behavioral control, underpinned by crucial factors: budget, data quality, policies, resources, and systems. This discussion aims to unveil correlations between variables and factors to address the gap between expectations and asset management implementation. Multiple Regression and Qualitative Comparative Analysis (QCA) results will be presented. Multiple Regression will reveal relationships between variables through Standardized Coefficients Beta (β^*) and significant values (P). Findings highlight a strong correlation between a manager's intention and perceived behavioral control, rein-forced by QCA results, emphasizing the manager's belief in their ability to execute asset management tasks. This underscores the pivotal role of perceived behavioral control in shaping intentions.

Perceived behavioral control is reinforced by three factors strongly connected to asset manager intentions: budget, data quality, and resources, supported by expert statements. Budget allocation reflects managerial priorities, influencing asset management positively. Poor data quality undermines manager confidence, while resource availability fosters effective asset management. Additionally, policies should align with target achievements to support manager attitudes. It is supported by several references that budget allocation reflects bridge owners' and managers' priorities, influencing service levels and life cycle costs [74]. Adequate funds specifically allocated for bridge asset management positively impact managers. Poor data quality can lead to erroneous decisions, inefficient resource allocation, and increased risks, affecting managers' confidence in executing asset management [40]. Knowledge, skills, organizational culture, and support are crucial for effective asset management, highlighting the importance of staff competence and organizational environment [7]. It can be concluded that effective bridge asset management hinges on budget allocation aligned with priorities, sufficient funding, high data quality to avoid errors and risks, and a supportive organizational environment fostering staff competence and a positive culture.

However, the Multiple Regression analysis indicated that Attitude and Subjective Norms do not align with asset manager intentions, influenced by budget inadequacies, data quality issues, and unclear policies. Subjective Norms inversely relate to intentions due to outdated policies and resource shortages, reflecting the need for updated guidelines and improved resources.

QCA identifies key conditions triggering asset manager intentions, with solutions emphasizing budget, data quality, resources, systems, Attitude, and Perceived Behavioral Control. Two dominant patterns emerge: voluntary asset management without policies but with adequate resources, and policy-adherent asset management irrespective of data conditions. These patterns reveal a lack of clear guidelines and uneven data quality.

Certified managers exhibit more supportive attitudes, subjective norms, and perceived behavioral control than non-certified counterparts, suggesting a need for certification alignment with managerial needs. Experienced managers and those in the Directorate rely on attitude and perceived behavioral control, while regional managers lean on attitude due to resource constraints.

To bolster their commitment to asset management, managers should prioritize initiatives aimed at enhancing their perceived control over operational tasks. This can be achieved through targeted investments in training and resource allocation, bolstering their confidence in executing asset management duties proficiently. Moreover, advocating for sufficient budgetary allocations dedicated to asset management endeavors is paramount, as it underscores the tangible benefits of adequate funding on operational outcomes. Simultaneously, managers must prioritize the maintenance and enhancement of data integrity, recognizing its pivotal role in informed decision-making processes. Furthermore, advocating for updated policies and guidelines reflective of contemporary best practices can provide managers with a structured framework for strategic decision-making. Additionally, acquiring relevant certifications and accumulating practical experience in asset management can significantly augment managers' competence and credibility in the field. By pursuing these avenues, managers can fortify their intention for proficient asset management, contributing to the overarching success of organizational asset management initiatives.

4.4 Summary of Intention Analysis

The current state of bridge asset management implementation in Indonesia falls far short of expectations, indicating a pressing need for improvement. Several key factors contribute to this deficiency. Firstly, there's a noticeable lack of commitment among asset managers to effectively execute bridge asset management strategies. This can be attributed to the poor quality of data that fails to accurately reflect field conditions, coupled with a limited understanding of the bridge asset management system among these managers. Furthermore, the scarcity of asset managers, along with inadequate resources, knowledge, and experience in asset management, exacerbates the situation. Budgetary constraints further hamper efforts to bolster resource capacity and support activities related to bridge asset management.

Research findings suggest that the willingness of bridge asset managers to oversee assets is heavily influenced by their perceived behavioral control. To enhance asset managers' willingness to implement bridge asset management, it is imperative to ensure that the budget is allocated according to the needs. Furthermore, managers need to validate data in accordance with applicable guidelines. Additionally, to maintain consistency in asset management, managers need to provide periodic training to their teams. Lastly, managers must comprehend the systems utilized in bridge preservation programming data processing to ensure that the system outputs can be utilized appropriately for the re-quired bridge maintenance.

Moreover, the attitudes and subjective norms of asset managers have not yet provided the necessary impetus for effective bridge asset management. This is due to their lack of confidence in the outcomes of the asset management process and limited knowledge about the assets under their purview. Insufficient human resources with reliable competencies further hinder the development of the asset manager's work environment.

Enhancing data quality and system robustness are pivotal in influencing asset managers' intention to engage in bridge asset management. Additionally, available resources must be augmented by screening managers with adequate experience and certifications. Establishing an optimal environment for effective bridge asset management is crucial, with particular emphasis on the development of human resources and the provision of necessary tools.

Recognizing the significance of bridge asset management knowledge is essential to prevent undesirable outcomes such as bridge failures. This underscores the importance of receiving high-quality data and utilizing a superior asset management system to bolster asset managers' intention to engage in bridge asset management.

Furthermore, the study proposes a novel hypothesis, suggesting that effective implementation of bridge asset management requires appropriate measures such as data validation, enhancement, and regular updates to both data and systems. Conducting regular socialization sessions on utilizing the bridge asset management system can enhance the capabilities of existing resources, leading to more accurate bridge preservation program results aligned with actual bridge conditions.

To improve bridge asset management in Indonesia, several practical steps can be taken. Firstly, allocate budget resources according to needs, addressing constraints and supporting necessary activities. Second, implement procedures to validate data quality based on relevant guidelines, enhancing decision-making confidence. Third, provide regular training sessions to enhance managers' understanding of bridge asset management systems and maintain consistency. Fourth, ensure managers comprehend the utilized systems, enabling effective utilization of outputs for maintenance. Fifth, screen managers are based on experience and certifications to ensure competency. Sixth, focus on developing human resources, providing necessary training and support. Lastly, establish an optimal environment conducive to effective management, emphasizing human resource development and providing necessary tools and support. Through these actions, organizations can address deficiencies and improve bridge asset management intention and effectiveness in Indonesia.

CHAPTER 5
IMPLEMENTATION OF HIGH PRECISION LIFE CYCLE COST ANALYSIS (HP-LCCA)

5.1 Motivation for Implementing HP-LCCA in Indonesia

Indonesia has extensive road infrastructure, the maintenance of which presents significant challenges to engineers and politicians alike. Roads and particularly bridges are key assets in supporting the national transport infrastructure. However, the management of these assets has encountered some significant issues, particularly concerned with the high cost of monitoring and maintaining the bridges. According to the report from the Directorate General of Highways 2023 for the second semester, the number of bridges on national roads with a length greater than 6 m totaled 19,377 units, with a combined length of 562 km [75]. Consequently, the government requires a strategic approach to effective asset management.

Bridges, as integral components of the road network system, function to traverse various obstacles such as rivers, valleys, road intersections, and other barriers. This function necessitates that bridge structures remain in optimal condition to effectively serve road users. To maintain the condition of bridges, management strategies should be implemented even before the bridge is constructed, ideally during the selection of the bridge's super-structure type. By selecting an appropriate superstructure type, maintenance costs can be anticipated earlier.

To estimate the costs required for bridge management throughout their service life, several countries have developed Life Cycle Cost Analysis (LCCA) applications, including the United States, the Czech Republic, and Japan. Generally, LCCA is a method for calculating future maintenance costs based on the current condition data of the object under review. When considering the condition assessment structures used, Japan and Indonesia have similarities in the range and the definitions of scores used to evaluate the condition of a bridge.

Japan has developed an application for conducting LCCA specifically for bridge structures. This application has a unique capability, as it predicts damage for each structural element that may experience physical deterioration. Physical damage includes issues such as rust on steel girders, structural cracks in concrete bridge elements, and other forms of physical damage. This approach is quite different from the concepts offered by the LCCA applications from the United States and the Czech Republic, where the calculations are intended for the entire bridge as a single unit rather than for individual elements.

To use this application, several critical data inputs are required. These include the condition values of the bridge's damaged structural elements, wherein all structural elements are divided into segments. Large, heavy elements are divided into many segments, while smaller, lighter elements are divided into fewer segments. This segmentation determines the rate of condition deterioration, which varies between segments depending on the level of damage each segment experiences. Due to its detailed analytical capabilities, this application is currently regarded as a High-Precision Life Cycle Cost Analysis tool.

This application differs from common tools used for LCCA, as it predicts the condition deterioration model for each type of structural damage found in the bridge's structural elements. Each segment of the damaged structural element has its own deterioration pre-diction model, which is considered to provide optimal results for bridge preservation programming.

The difference between applying condition deterioration to entire bridges versus applying it to individual bridge elements raises the question of whether this approach can effectively reduce life cycle costs (LCC). This represents a unique innovation that has not yet been addressed in other LCC studies conducted to date.

Previous studies on bridge infrastructure have extensively explored life cycle cost (LCC) comparisons as a means of optimizing structural design parameters. Findings from these investigations indicate that bridges with slab concrete superstructures and spans shorter than 12 meters generally represent the most cost-effective solution over their service life [4]. Moreover, the choice of construction material, whether concrete or steel, has been shown to exert a significant influence on overall LCC outcomes [5]. In terms of maintenance strategies, evidence consistently demonstrates that preventive maintenance not only minimizes total LCC but also provides a balanced approach to safety, cost efficiency, and environmental performance, thereby underscoring its pivotal role in sustainable bridge asset management [6].

Despite these advancements, existing literature reveals a notable gap: comparative analyses examining how different bridge condition assessment methods affect LCC outcomes remain scarce. Such comparisons are crucial, as variations in assessment approaches may significantly influence optimization results. Addressing this gap necessitates a rigorous evaluation of alternative LCC modeling frameworks to determine which approach delivers the greatest economic and operational value and can serve as a standardized procedure for applying LCCA tools in the Indonesian context.

To develop a more robust and optimized LCCA framework, this research seeks to address several key questions. First, to what extent does a significant correlation exist between the condition assessment methodologies employed in Indonesia and those utilized in Japan? Second, how might this correlation shape or alter the final LCCA calculations? Finally, what analytical methods or optimization techniques can be implemented to refine LCCA results and support more informed decision-making in bridge asset management?

5.2 Results of HP-LCCA Application

5.2.1 Alignment of Non-Physical and Physical Assessment Perceptions

According to Gniazdowski (2023), the correlation analysis between nominal and numerical data focuses on measuring the strength of a linear correlation relationship between them [76]. Cuttler Carrie et al. (2020) emphasize that correlation analysis is a method to evaluate the strength and direction of the relationship between two variables [77]. Correlation analysis is a fundamental tool for multivariate data analysis, used to estimate the strength of the linear association between two variables [78]. However, it is important to note that correlation does not imply causation [79]. This study will analyze the relationship between the bridge condition assessment criteria in Indonesia and Japan.

Correlation analysis is a nonexperimental research method in which two variables are measured to evaluate their statistical relationship, with minimal or no control over extraneous variables. The direction of this correlation can be either positive or negative, indicating whether the variables change in the same direction or in opposite directions, respectively. The primary purpose of correlation research is to test the strength of association between variables, providing valuable insights into complex real-world relationships and aiding in the development of theories and predictions [80]. However, this method has notable limitations, such as its assumption of a linear relationship and its sensitivity to the range of observations. Moreover, correlation analysis is not appropriate for assessing the agreement between two methods aimed at measuring the same value. In such cases, more suitable alternatives include the intraclass coefficient and Bland–Altman's limits of agreement [81].

Data collection through questionnaires for aligning perceptions serves as primary data while gathering bridge condition data from visual inspections conducted by Japanese inspectors serves as secondary data. The bridge condition assessments performed by inspectors in Japan are subsequently re-evaluated by bridge inspection experts in Indonesia to determine the correlation between these two methods of condition assessment.

The total number of inspectors participating in the questionnaire was 77 respondents, comprising 43 bridge inspectors from Indonesia and 34 from Japan, as shown in Table 5-1. The questionnaire was designed with two methods of condition assessment, namely Indonesian and Japanese, aiming for objective responses from representatives of each country to the questions listed in the questionnaire. It is worth noting that the questionnaire included 13 questions regarding damages to concrete girder bridge elements presented with images and descriptions, along with condition assessments based on Indonesian (0–5) and Japanese (a–e) criteria.

From Table 5-1, it can be observed that the majority of respondents are male, with the nationality of respondents being fairly balanced between Indonesia and Japan. Additionally, most respondents are under the age of 35 and have less than 5 years of experience. On the other hand, nearly half of the respondents are over the age of 35, with the majority having more than 5 years of experience.

Table 5-1. Respondent demographics.

Variable	Category	Frequency	Percentage (%)
Gender	Male	72	93.51
	Female	5	6.49
Nationality	Indonesia	43	55.84
	Japan	34	44.16
Age	<25	4	5.19
	25–30	24	35.06
	30–35	12	15.58
	35–40	4	5.19
	40>	30	38.96
Experience	<1 Years	6	7.79
	1–3 Years	18	23.38
	3–5 Years	23	29.87
	5–10 Years	19	24.68
	>10 Years	11	14.29
Certification	Certified	47	61
	Not Certified	30	39

Table 5-2. Pictures of damage types on concrete girder elements.

Image 1 	Image 2 	Image 3 	Image 4 	Image 5 
Image 6 	Image 7 	Image 8 	Image 9 	Image 10 
	Image 11 	Image 12 	Image 13 	

Table 5-3. Pictures of damage types on steel girder elements.

Image 1 	Image 2 	Image 3 	Image 4 	Image 5 
Image 6 	Image 7 	Image 8 	Image 9 	Image 10 
Image 11 	Image 12 	Image 13 	Image 14 	Image 15 
	Image 16 	Image 17 	Image 18 	

The design of the questionnaire consists of a collection of images from inspections of selected bridges, deemed representative based on discussions with bridge experts in both Indonesia and Japan. Table 5-2 and Table 5-3 presents photos of damage to elements of concrete and steel girder bridges, such as reinforced concrete girders, prestressed concrete girders, and steel girders selected as research subjects. Each type and severity of damage has been selected to achieve a more accurate distribution of assessments. Notably, there is a difference in crack damage between concrete girders and prestressed concrete girders. Even with the same crack width, the severity of the damage will vary between these two types of girders. The questionnaire also includes explanations regarding the types and sizes of the damage depicted in the available photos.

The results of the questionnaire survey presented in Table 5-4 show a pattern of inspection results that appear identical. This is indicated by the number of selections for good condition ratings using both non-physical and physical methods. From the table, it is evident that there is a consistent pattern in the inspection results, with ten out of thirteen types of damage (77%) exhibiting similar patterns, while the remaining three types of damage (23%) show slight differences in assessment perceptions. The values in Table 5-5 will be normalized for the correlation analysis in order to obtain the correlation values between the two models.

In contrast to the concrete girders, the questionnaire results for the steel girders indicate a markedly different pattern of condition ratings between the Non-Physical and Physical evaluation methods, as shown in Tables 5–5. Only nine images exhibit consistent rating patterns, resulting in just ten matching evaluations (56%) between the two methods for steel girders. This level of agreement is notably lower than that observed for the concrete girders, which reached 77%. These findings warrant further discussion and a more in-depth investigation to better understand the underlying causes of this discrepancy.

Table 5-4. The results of the perception alignment questionnaire of concrete girders.

	Non-Physical Assessment Score								Physical Assessment Score						
	CS_0	**CS_1**	**CS_2**	**CS_3**	**CS_4**	**CS_5**	**CS_VAL**	**n**	**CS_a**	**CS_b**	**CS_c**	**CS_d**	**CS_e**	**CS_VAL**	**n**
Image_1	1	9	30	1	2	0	CS_2	43	0	8	20	6	0	CS_c	34
Image_2	1	31	9	1	1	0	CS_1	43	4	9	16	0	5	CS_c	34
Image_3	0	3	36	2	2	0	CS_2	43	0	1	3	26	4	CS_d	34
Image_4	0	10	31	2	0	0	CS_2	43	0	1	6	27	0	CS_d	34
Image_5	0	3	34	5	1	0	CS_2	43	0	1	2	27	4	CS_d	34
Image_6	0	0	31	10	2	0	CS_2	43	0	0	1	25	8	CS_d	34
Image_7	0	1	31	10	1	0	CS_2	43	0	0	2	24	8	CS_d	34
Image_8	0	3	6	29	5	0	CS_3	43	0	0	0	9	25	CS_e	34
Image_9	0	0	5	32	6	0	CS_3	43	0	0	0	3	31	CS_e	34
Image_10	0	0	7	26	9	1	CS_3	43	0	0	0	11	23	CS_e	34
Image_11	0	1	13	25	4	0	CS_3	43	0	0	3	17	14	CS_e	34
Image_12	0	8	23	10	2	0	CS_3	43	0	1	13	16	4	CS_d	34
Image_13	0	14	25	4	0	0	CS_2	43	1	2	29	0	2	CS_c	34

Table 5-5. The results of the perception alignment questionnaire of steel girders

	Non-Physical Assessment Score								Physical Assessment Score						
	CS_0	CS_1	CS_2	CS_3	CS_4	CS_5	CS_VAL	n	CS_a	CS_b	CS_c	CS_d	CS_e	CS_VAL	n
Image_1	0	0	15	23	5	0	CS_3	43	0	2	1	15	16	CS_d	34
Image_2	0	0	6	34	3	0	CS_3	43	0	2	1	22	9	CS_e	34
Image_3	0	0	2	34	6	1	CS_3	43	0	1	2	17	14	CS_b	34
Image_4	0	14	25	4	0	0	CS_2	43	1	7	17	5	4	CS_c	34
Image_5	1	11	24	7	0	0	CS_2	43	8	8	17	1	0	CS_a	34
Image_6	0	1	20	17	5	0	CS_2	43	0	11	12	10	1	CS_b	34
Image_7	0	6	33	4	0	0	CS_2	43	0	16	5	13	0	CS_e	34
Image_8	0	18	23	2	0	0	CS_2	43	0	24	3	7	0	CS_b	34
Image_9	0	3	33	6	1	0	CS_2	43	0	5	7	19	3	CS_d	34
Image_10	0	0	13	26	4	0	CS_3	43	0	2	1	22	9	CS_d	34
Image_11	0	0	15	25	3	0	CS_3	43	0	0	3	28	3	CS_d	34
Image_12	0	1	17	23	2	0	CS_3	43	0	4	5	17	8	CS_d	34
Image_13	0	0	16	25	2	0	CS_3	43	0	0	2	21	11	CS_d	34
Image_14	0	0	1	28	14	0	CS_4	43	0	0	1	4	29	CS_d	34
Image_15	0	6	28	9	0	0	CS_2	43	0	1	8	12	13	CS_b	34
Image_16	0	5	23	15	0	0	CS_3	43	0	1	2	8	23	CS_a	34
Image_17	6	19	16	1	1	0	CS_2	43	24	9	1	0	0	CS_e	34
Image_18	0	21	20	1	1	0	CS_1	43	3	2	26	1	2	CS_c	34

For condition assessment results of concrete girders using the non-physical inspection method (figure 5-1), Image 3 has the highest objectivity, with a percentage of correct answers (based on expert validation ranging from 0% at worst to 100% at best) at 84%, while Image 12 has the lowest objectivity with a percentage of correct answers of 23%. For condition assessment results according to the physical inspection method, Image 9 has the highest objectivity with a percentage of correct answers of 91%, while Image 11 has the lowest objectivity with a percentage of correct answers of 41%. The average objectivity level for both assessment methods is 66% for non-physical and 69% for physical methods. This average indicates that the assessment results of both methods have a similar level of objectivity.

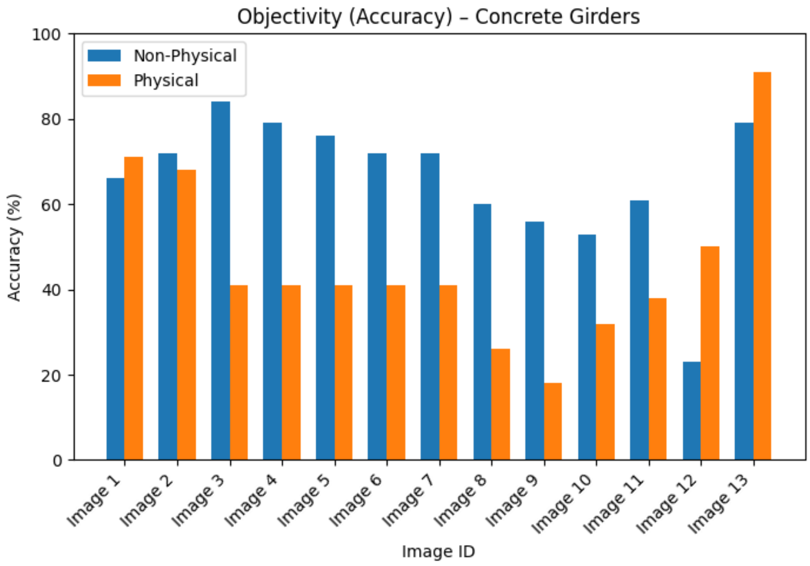


Figure 5-1. Percentage of objectivity of condition assessment results of concrete girders.

In contrast to the concrete girders, the steel girders exhibited a lower level of assessment objectivity, as illustrated in Figure 5-2. The average objectivity level for the Non-Physical evaluation was 57%, whereas the Physical evaluation yielded only 36% agreement with the expert-validated results. The Non-Physical method achieved a maximum objectivity of 79% and a minimum of 33%, while the Physical method ranged from a maximum of 82% to a minimum of 0%. For the Physical evaluation of steel girders, three images—Image 7, Image

16, and Image 17—displayed results that differed considerably from the respondents' assessments. This discrepancy may have been influenced by several factors, including insufficient clarity in the information provided in the questionnaire (either in the images or damage descriptions), which may have led to inaccurate judgments. Overall, the average objectivity level for the steel girder damage assessments was 57% for the Non-Physical method and 36% for the Physical method. These findings clearly indicate a decline in assessment objectivity for steel girders under both evaluation approaches when compared with the objectivity levels observed for the concrete girders.

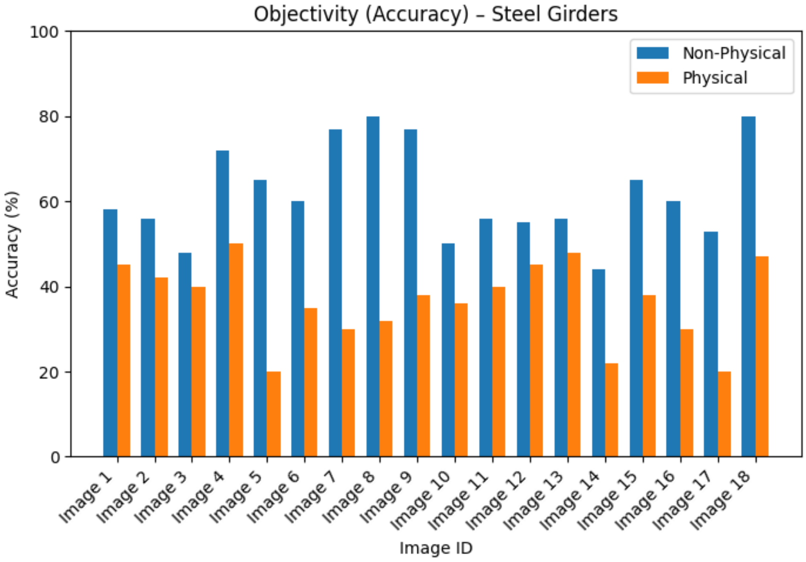


Figure 5-2. Percentage of objectivity of condition assessment results of steel girders.

Based on the data analysis, several patterns are evident in Figure 5-4, illustrating the relationship between the non-physical inspection method (Indonesian) and the physical inspection method (Japanese). These results were processed using Excel's version 2409 (Build 18025.20104) correlation analysis function, yielding a range of values from −1 to 1. A value of −1 indicates that the two variables do not have a strong relationship, while a value of 1 indicates a strong relationship between the two variables [82–84].

Figure 5-3 presents the questionnaire results illustrating the relationship between two assessment methods—Non-Physical and Physical—applied to two types of structural elements: concrete girders and steel girders. The analysis reveals a generally strong correspondence between the two sets of evaluation criteria. For the concrete girders, the correlation matrix indicates a strong positive relationship between condition states "0"–"1" and "a"–"c," suggesting that both evaluation methods tend to classify early-stage deterioration in a similar manner. At more advanced deterioration levels, such as "2" with "d" and "3" with "e," the correlation becomes even more pronounced.

In contrast, the steel girders exhibit a different pattern. Clear correlations are visible at the initial and final stages of deterioration—specifically between condition states "0" and "a," and "4" and "e." However, condition state "2" shows bias toward both "b" and "c," while condition state "3" displays bias toward "d" and "e." This indicates greater variability and less consistency between the two assessment methods when evaluating intermediate deterioration stages for steel girders.

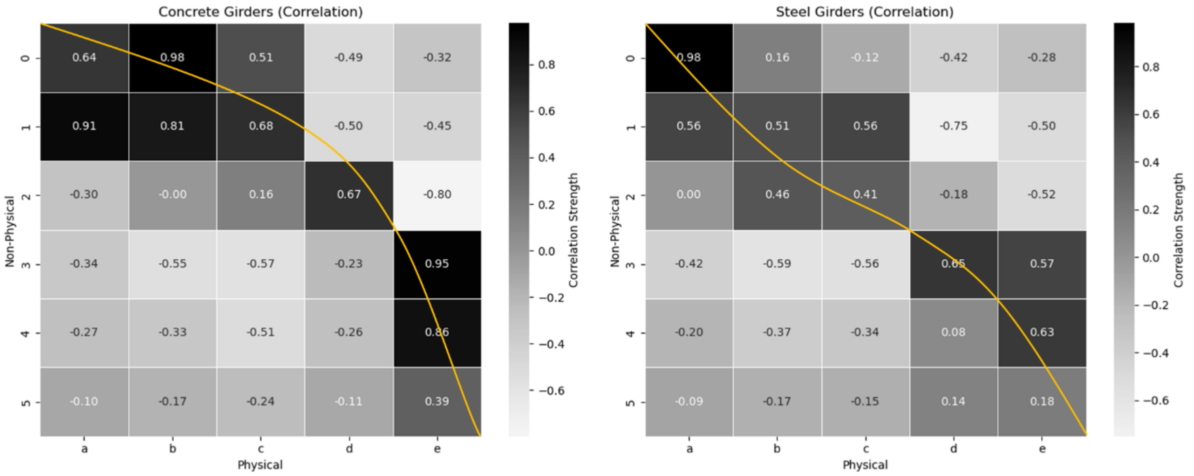


Figure 5-3. Correlation matrix between physical and non-physical assessment based on questionnaire for inspectors.

Based on the correlation analysis results for both concrete and steel girders, the condition ratings for concrete elements at the early deterioration stages appear to exhibit notable bias. This is likely due to the need for additional specialized tools—such as crack meters or hammers—to accurately determine the severity of damage. In such cases, visual judgement alone is insufficient to reliably establish condition ratings, particularly for concrete elements. In contrast, steel girders display clearer and more consistent patterns at the early stages of deterioration. This is likely because surface-related defects—such as coating deterioration and corrosion—are more readily identifiable through visual observation without requiring specialized equipment. Consequently, to achieve more objective assessments, the use of supplementary inspection tools is far more critical for concrete girders than for steel girders during visual evaluations.

To enhance the objectivity of the assessment, an additional evaluation of bridge conditions was conducted using concrete and steel girder bridge samples previously inspected by expert bridge inspectors in Japan through the Physical assessment method. These same samples were subsequently re-evaluated by expert bridge inspectors in Indonesia using the Non-Physical method to examine the resulting assessment patterns. In addition, historical damage records comprising 1,004 concrete girder samples (Table 5-6) and 1,143 steel girder samples (Table 5-7) from Kochi Prefecture, Japan, were analyzed using both evaluation models. For the concrete girders, the dataset included 457 samples of cracking, 209 samples of delamination, 233 samples of exposed reinforcement, and 105 samples of spalling. For the steel girders, the dataset consisted of 699 samples of coating deterioration and 444 samples of corrosion.

Based on the data presented in Tables 5-6 and 5-7, a correlation analysis was also conducted to examine the relationship between the Non-Physical and Physical evaluation methods. The data processing results, as shown in Figure 5-4, reveal two striking differences.

Overall, the Non-Physical evaluation results indicate that condition state 2 is highly dominant for both concrete and steel girders. For both types of structural elements, condition state 2 exhibits a wide range of rating bias. In the case of concrete girders, condition state 2 shows correlation values ranging from “c” to “e,” whereas for steel girders the bias extends more prominently from “b” to “e.”

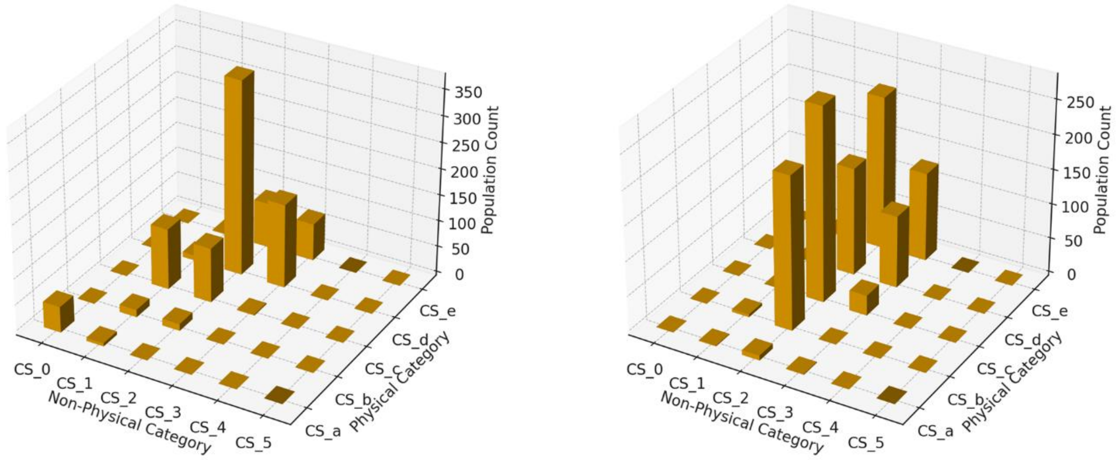
Table 5-6. Results of bridge expert perception for concrete girder bridge.

Damage Sample	Type of Damage	Non-Physical Assessment Score	Physical Assessment Score
Sample 1	Delamination	2	e
Sample 2	Delamination	3	e
Sample 3	Spalling	2	c
~	~	~	~
Sample 101	Cracking	2	d
Sample 102	Cracking	2	d
Sample 103	Exposed Rebar	2	d
~	~	~	~
Sample 1001	Exposed Rebar	2	d
Sample 1002	Exposed Rebar	2	d
Sample 1003	Exposed Rebar	2	d
Sample 1004	Exposed Rebar	2	d

Table 5-7. Results of bridge expert perception for steel girder bridge.

Damage Sample	Type of Damage	Non-Physical Assessment Score	Physical Assessment Score
Sample 1	Corrosion	2	b
Sample 2	Coating	2	e
Sample 3	Corrosion	2	b
~	~	~	~
Sample 211	Coating	2	c
Sample 212	Corrosion	2	b
Sample 213	Coating	2	e
~	~	~	~
Sample 1050	Corrosion	3	d
Sample 1051	Coating	3	e
Sample 1052	Corrosion	3	d
Sample 1053	Corrosion	3	d

This condition likely arises from differences in how each method determines the condition rating, suggesting the need for a more in-depth examination of the specific assessment criteria that contribute to these discrepancies in the evaluation of concrete and steel girders.



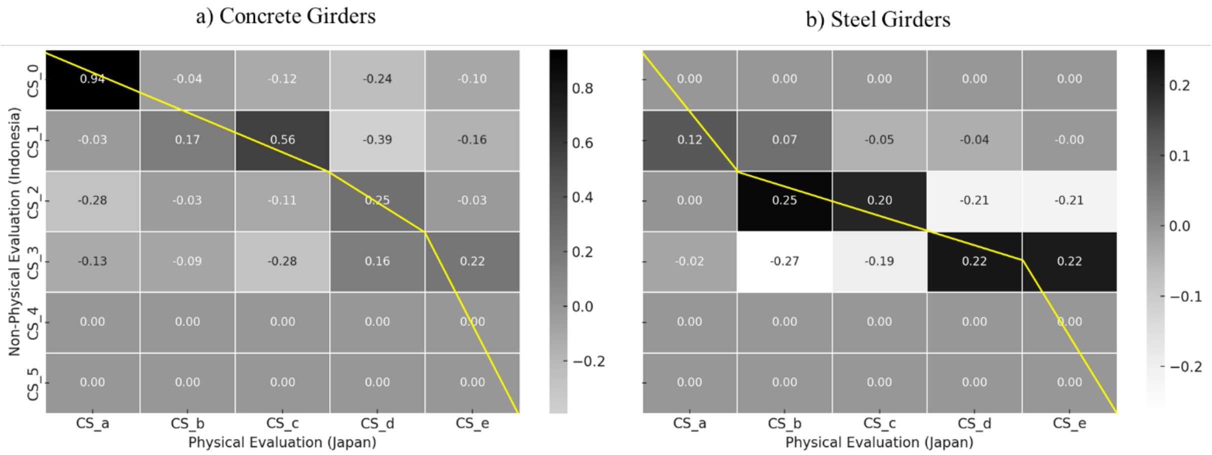
a) Concrete Girders

b) Steel Girders

Figure 5-4. Bar chart depicting the relationship between the population of non-physical and physical assessments.

Based on the correlation analysis results presented in Figure 5-5, which illustrates the correlation matrix between the Non-Physical and Physical assessment methods, a strong positive relationship is evident between the two approaches. The association between corresponding variables appears positive overall, particularly for the pairs 0–a, and 3–e. However, the relationship for condition state 1 differs between the two girder types: for concrete girders, state 1 shows a strong correlation with “c,” whereas for steel girders, state 1 correlates more strongly with “a.”

For the concrete girder evaluations, condition states 2 and 3 exhibit clear and sequential correlations with “d” and “e,” respectively. In contrast, for the steel girders, condition state 2 displays bias toward both “b” and “c,” and condition state 3 shows bias toward both “d” and “e.” To understand how such rating biases arise, further examination of the underlying assessment criteria may help identify the factors contributing to these inconsistencies and guide improvements in condition evaluation practices.


a) Concrete Girders

b) Steel Girders

Figure 5-5. Correlation matrix between non-physical and physical assessment (expert).

When the expert evaluation patterns are compared with those produced by inspectors through the questionnaire, clear differences in assessment objectivity become evident. The experts demonstrate a higher level of objectivity, particularly in the early stages of girder deterioration. This is reflected in the lower degree of rating bias observed in the expert evaluations compared with those of the inspectors. These findings suggest that professional experience plays a critical role in enhancing the accuracy and precision of condition assessments, enabling experts to provide more objective evaluations that more closely correspond to the actual damage observed in the field.

To identify the sources of bias in bridge girder condition assessments, each damage type must be examined in detail to better understand the correlation patterns between the Non-Physical and Physical evaluation methods. In this study, six damage types formed the basis of the correlation analysis: four associated with concrete girders—cracking, delamination, exposed reinforcement, and spalling—and two associated with steel girders—coating deterioration and corrosion. These damage categories were analyzed using a normalized Transition Probability Matrix (TPM) to detect significant correlation patterns across the variables. Two probability thresholds were used: ≥0.50 to indicate strong correlations and 0.30–0.49 to indicate moderate correlations, following Gignac and Szodorai (2016), who note that correlations above 0.30 typically represent meaningful associations. The probability values generated for each correlation pair were then summed to identify the highest cumulative probability, which was subsequently selected as the representative correlation for that damage type.

A total of 457 samples of cracking damage, 209 samples of concrete delamination, 233 samples of exposed reinforcement, and 105 samples of spalling in concrete girders, along with 699 samples of coating deterioration and 444 samples of corrosion in steel girders, were analyzed using the TPM method. The results of this analysis are expected to provide deeper and more fundamental insights into which assessment criteria contribute to bias in bridge condition evaluations.

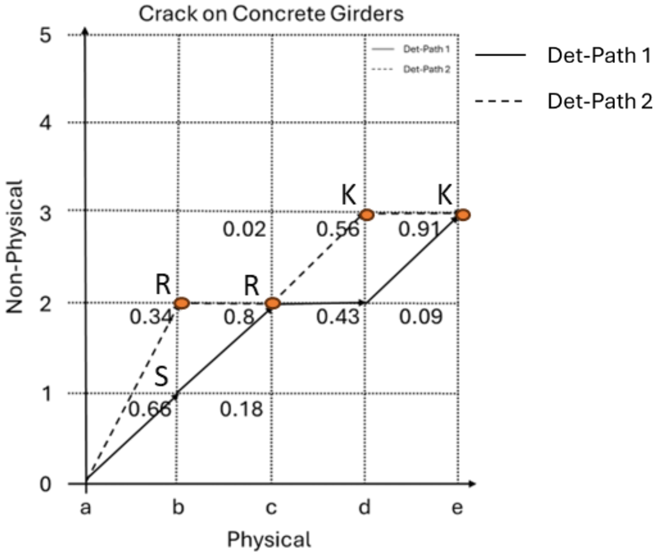


Figure 5-6. Graph of the relationship between Non-Physical and Physical evaluation values of crack damage to concrete girders.

Figure 5-6 presents the correlation model for cracking damage, where two probability sets were identified: (0–a, 1–b, 2–c, 2–d, 3–e) and (0–a, 1–b, 2–b, 2–c, 3–d, 3–e). The results exhibit a nearly linear relationship between the two methods, though discrepancies appear at Physical grades a, b, and d relative to Non-Physical condition states 0–3. At correlation level 0–a, both models align perfectly, indicating identical criteria for undamaged elements. For 1–b and 2–b, probabilities of 0.66 and 0.34 were observed, influenced primarily by the Degree (R) and Extent (K) parameters in the Non-Physical method. Both frameworks use a 0.2 mm crack-width threshold for rating “1,” but differ in how extent is defined, the Physical method classifies extent by surface crack spacing, while the Non-Physical method applies a 30 % area threshold. Similar divergence occurs at 2–d (0.43) and 3–d (0.56), confirming that variation between methods originates from differences in extent and quantity definitions.

These phenomenon of discrepancies stem from methodological distinctions: the Non-Physical method emphasizes the proportion of surface damage, whereas the Physical approach focuses on measurable characteristics such as crack spacing and width. Consequently, small interpretive variations may produce divergent ratings, particularly where data are limited. This highlights the inherent complexity and subjectivity of assessing cracking damage under differing evaluation frameworks.

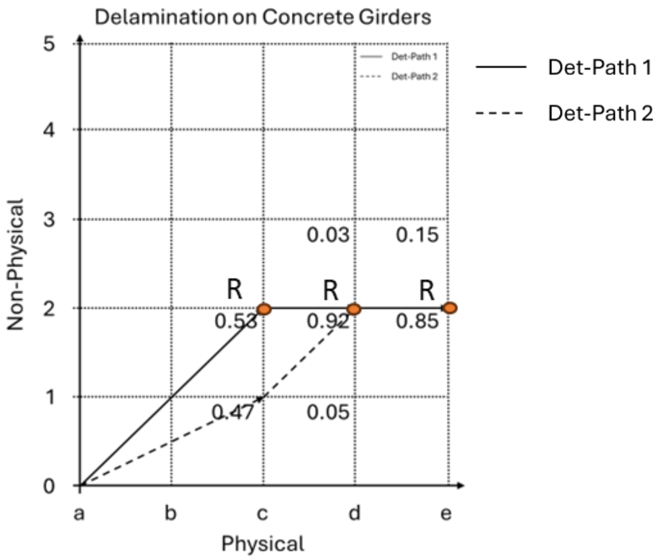


Figure 5-7. Graph of the relationship between Non-Physical and Physical evaluation values of delamination damage to concrete girders.

Figure 5-7 illustrates the correlation model for delamination, showing two probability sets, (0–a, 1–b, 2–c, 2–d, 2–e) and (0–a, 1–b, 1–c, 2–d, 2–e), with most cases corresponding to Physical grades c–e. Correlations 1–c (0.47) and 2–c (0.53) demonstrate that discrepancies arise when delamination exceeds 30 % of the surface area without exposed reinforcement. In such cases, the Non-Physical method assigns Condition State 2, whereas the Physical method emphasizes reinforcement visibility and rates the same damage as category c. This suggests that differences in damage quantification rather than conceptual inconsistencies account for the observed variations.

Similarly, Figure 5-8 shows the correlation model for exposed reinforcement, revealing a nearly linear trend between both methods across two probability sets: (0–a, 1–b, 2–c, 2–d, 3–e) and (0–a, 1–b, 1–c, 2–d, 3–e). The strong consistency reflects the shared emphasis on corrosion severity as a determinant of girder performance. Minor differences at condition 1 (aligning with Physical grades b and c) are attributed to limited data at early corrosion stages, underscoring the need for broader datasets to reduce bias.

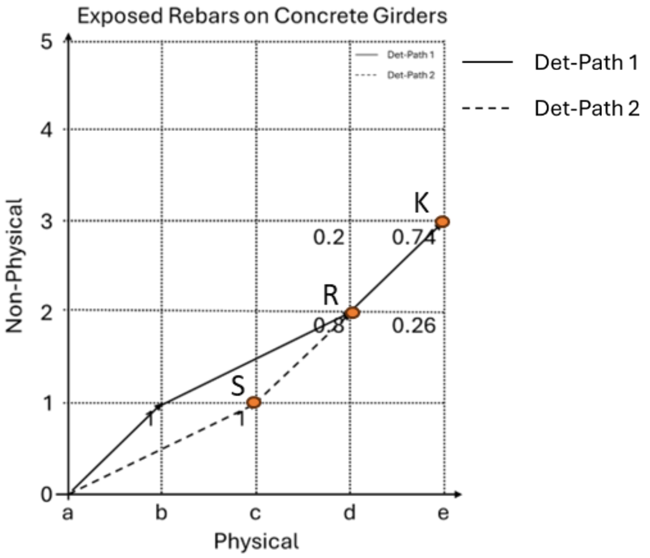


Figure 5-8. Graph of the relationship between Non-Physical and Physical evaluation values of exposed rebars damage to concrete girders.

Figure 5-9 presents the correlation model for spalling, identifying two possible probability paths: (0–a, 1–b, 1–c, 2–d, 2–e) and (0–a, 1–b, 1–c, 1–d, 1–e). Most samples were classified within Physical categories c–e, where severity is governed primarily by reinforcement exposure. In contrast, the Non-Physical method links severity mainly to the proportion of the affected surface area; because none of the samples exceeded 30% of the girder's cross-sectional area, higher severity ratings did not appear in the Non-Physical results. This contrast highlights a fundamental methodological distinction: the Physical evaluation framework prioritizes indicators such as reinforcement visibility, whereas the Non-Physical approach emphasizes the spatial extent of surface deterioration. When the cumulative probabilities along the two correlation paths are calculated, both yield identical values. Consequently, determining the more appropriate correlation pathway requires additional comparison with the results from concrete girder evaluations—both from the questionnaire and expert assessments—to validate which pattern aligns more consistently with empirical evaluation behavior.

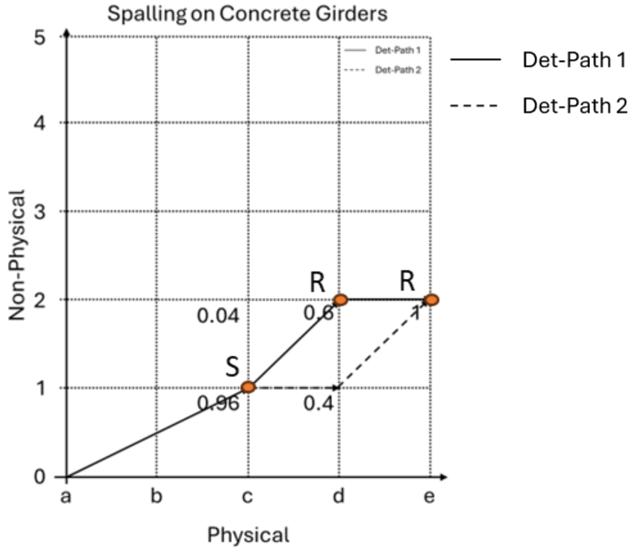


Figure 5-9. Graph of the relationship between Non-Physical and Physical evaluation values of spalling damage to concrete girders.

Moving to steel girders, Figure 5-10 illustrates the correlation model for coating damage, with the first probability set consisting of 0–a, 1–a, 2–c, 2–d, and 2–e, and the second comprising 0–a, 1–a, 2–c, 3–d, and 3–e. The evaluation results reveal that the deterioration of the coating surface is strongly influenced by the extent of the damaged area, where the data generally show that paint degradation occurs uniformly across the girder surface. In the Physical evaluation method, a coating loss exceeding 50% of the cross-sectional area corresponds to the most severe category (e), whereas in the Non-Physical method, deterioration affecting as little as 30% of the surface area is sufficient to assign a poor condition rating. This methodological distinction explains the observed gap between condition levels d and e in the Physical evaluation and their corresponding values of 2 and 3 in the Non-Physical evaluation. The results highlight how differences in threshold criteria for damage severity contribute to divergence between the two assessment approaches.

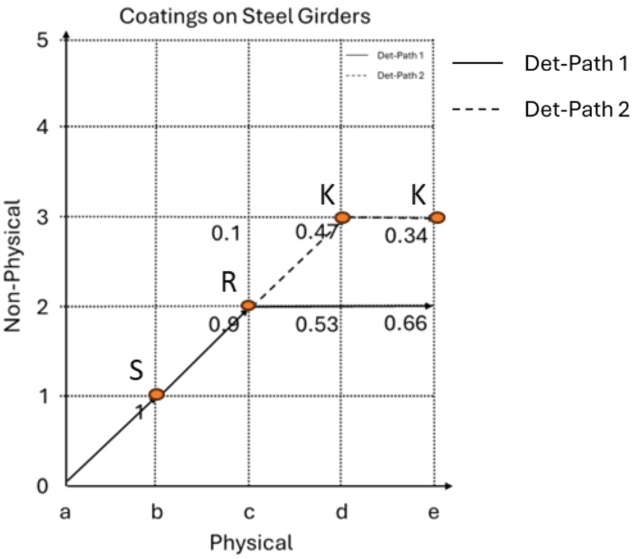


Figure 5-10. Graph of the relationship between Non-Physical and Physical evaluation values of coatings damage to steel girders.

Finally, Figure 5-11 presents the correlation model for corrosion damage in steel girders, with the first probability set comprising 0–a, 1–a, 2–c, 2–d, and 3–e, while the second includes 0–a, 1–a, 2–c, 3–d, and 3–e. The evaluation results reveal a notable gap in the assignment of condition level d within the Physical method compared with condition levels 2 and 3 in the Non-Physical method. This discrepancy is likely attributable to differences in the underlying assumptions regarding the affected surface area. In the Physical evaluation, more severe ratings are applied only when corrosion affects more than 50% of the girder surface, whereas in the Non-Physical evaluation, a threshold of 30% deterioration is already considered sufficient to classify the element as severely damaged. These distinct threshold criteria result in divergences between the two approaches, highlighting how variations in the definition of critical damage levels influence the overall assessment outcomes.

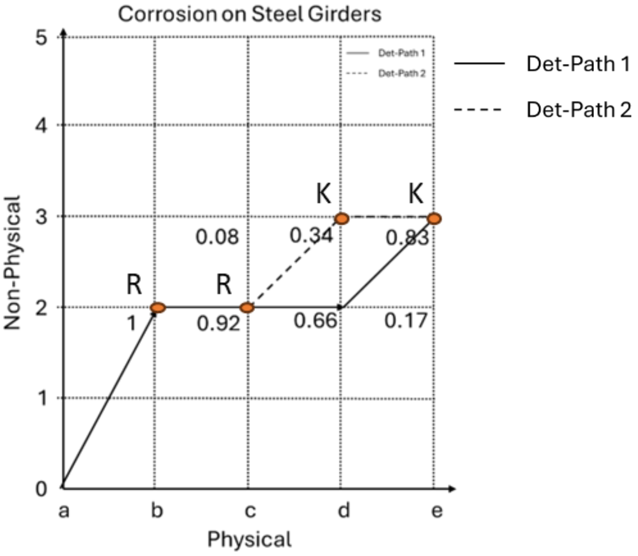


Figure 5-11. Graph of the relationship between Non-Physical and Physical evaluation values of corrosion damage to steel girders.

Overall, the correlation analysis across the six damage types, cracking, delamination, exposed reinforcement, spalling, coating deterioration, and corrosion, reveals a consistent pattern: damage extent is the primary factor that differentiates the Physical and Non-Physical evaluation frameworks. The two probability paths observed across all correlation graphs further reinforce this conclusion. The Non-Physical method classifies deterioration predominantly based on the proportion of the affected area, while the Physical method relies on quantifiable physical indicators, such as crack spacing, crack width, the visibility of reinforcement, the coatings deterioration, and surface corrosion. This fundamental difference in the characterization of deterioration accounts for much of the divergence observed between the two assessment methods.

In the Non-Physical system, evaluation proceeds sequentially from the Nature Mark (S) to the Implication Mark (P), with each girder rated as a single unit rather than by segment. Japanese historical data were likewise assessed at the element level. In this framework, ″S″ = 1 indicates observed damage (corresponding to Physical ″b″), while ″S″ = 0 aligns with Physical ″a.″ The Degree (R) and Extent (K) parameters primarily control variation: ″R″ = 1 when crack width ≥ 0.2 mm, and ″K″ = 1 when affected area exceeds 30 %. The Function (F) and Implication (P) parameters are activated when loss of serviceability or structural interaction occurs.

A notable finding is the presence of dual correlation probabilities in intermediate condition states, such as 2–d and 3–d for cracking damage. This occurs because the Non-Physical method distinguishes extent using the 30 % threshold, while the Physical method employs both crack spacing (< 50 cm) and width categories (< 0.1 mm, 0.1–0.2 mm, ≥ 0.2 mm). For example, a crack width of 0.3 mm and spacing under 50 cm but with area < 30 % yields Non-Physical Condition 2 (″S″ = 1, ″R″ = 1, ″K″ = 0, ″F″ = 0, ″P″ = 0) and Physical Mark “d.” If the area exceeds 30 %, the Non-Physical state rises to 3, while the Physical mark remains “d.”

Similar patterns are observed across other damage types, such as coating deterioration and corrosion. These findings indicate that discrepancies between the evaluation methods largely arise from differences in how damage extent is defined and recorded. Inadequate documentation of affected areas further amplifies subjectivity in the assessment process. In addition, the recommended deterioration path is based on the probability of the worst-condition state, which is necessary to ensure that all potential conditions are captured and systematically programmed for intervention planning. To address these issues, segmenting the damaged elements improves both accuracy and representativeness, enabling extent-of-damage evaluations to better reflect actual field conditions.

Table 5-8. Regression analysis results of the relationship between non-physical and physical assessment of questionnaire and expert results of concrete girders.

		0–a	**0–b**	**0–c**	**0–d**	**0–e**
Inspectors	Multiple R	0.6396	0.9765	0.511	−0.4946	−0.3187
	Sig–F	0.0186	1.131×10^{-8}	0.0743	0.0857	0.2885
Expert	Multiple R	0.9409	−0.0377	−0.1207	−0.2449	−0.0983
	Sig–F	0	0.2332	0.000126	3.58×10^{-15}	0.00183
		1–a	**1–b**	**1–c**	**1–d**	**1–e**
Inspectors	Multiple R	0.9101	0.8052	0.6829	−0.4954	−0.4524
	Sig–F	1.575×10^{-5}	0.00089	0.01008	0.0852	0.1206
Expert	Multiple R	−0.026	0.174	0.5637	−0.3931	−0.16497
	Sig–F	0.4101	2.86×10^{-8}	2.68×10^{-85}	1.902×10^{-38}	1.46×10^{-7}
		2–a	**2–b**	**2–c**	**2–d**	**2–e**
Inspectors	Multiple R	−0.2962	−0.00496	0.1584	0.6699	−0.7969
	Sig–F	0.3257	0.9872	0.6053	0.0122	0.0011
Expert	Multiple R	−0.2781	−0.03031	−0.1112	0.2492	−0.027
	Sig–F	2.706×10^{-19}	0.3373	0.00042	1.134×10^{-15}	0.3923
		3–a	**3–b**	**3–c**	**3–d**	**3–e**
Inspectors	Multiple R	−0.3351	−0.5479	−0.5654	−0.2335	0.9534
	Sig–F	0.2631	0.0526	0.044	0.4426	4.628×10^{-7}
Expert	Multiple R	−0.1323	−0.0913	−0.2815	0.163	0.2204
	Sig–F	2.59×10^{-5}	0.0038	9.52×10^{-20}	2.05×10^{-7}	1.652×10^{-12}
		4–a	**4–b**	**4–c**	**4–d**	**4–e**
Inspectors	Multiple R	−0.2678	−0.3311	−0.5118	−0.2638	0.8635
	Sig–F	0.3763	0.2691	0.0738	0.3838	0.0001426
Expert	Multiple R	0	0	0	0	0
	Sig–F	0	0	0	0	0
		5–a	**5–b**	**5–c**	**5–d**	**5–e**
Inspectors	Multiple R	−0.1031	−0.1737	−0.2365	−0.1057	0.3864
	Sig–F	0.7375	0.5702	0.4367	0.731	0.1922
Expert	Multiple R	0	0		0	0
	Sig–F	0	0	0	0	0

Based on various analysis results, the relationship between the two inspection methods (non-physical and physical) for concrete girders can be summarized as shown in Table 5-8.

Subsequently, the regression analysis results from the Questionnaire and Expert assessments were compared. The values of Multiple R and Significance (F) were used as benchmarks for selecting the best correlation between non-physical and physical methods, ensuring that no negative correlations were chosen and that the significance value exceeded 0.05. According to these criteria, the most appropriate correlations selected are “0–a”, “1–b”, “2–d”, “3–e”, “4–e”, and “5–e”. Similarly, the regression analysis conducted to examine the correlation between the Non-Physical and Physical evaluation methods for steel girders, presented in Table 5-9, shows a distinct set of relationships. The correlation pattern that best fits the data, based on the observed significance levels, is “0–a,” “1–a,” “2–b,” “3–d,” “4–e,” and “5–e.” This sequence represents the most statistically consistent mapping between the two assessment frameworks for steel girder deterioration.

Table 5-9. Regression analysis results of the relationship between non-physical and physical assessment of questionnaire and expert results of steel girders.

		0–a	**0–b**	**0–c**	**0–d**	**0–e**
Inspectors	Multiple R	0.9804	0.1611	−0.1233	−0.4229	−0.277
	Sig–F	1.0247 x 10^{-12}	0.523	0.6261	0.0804	0.2658
Expert	Multiple R	0	0	0	0	0
	Sig–F	0	0	0	0	0
		1–a	**1–b**	**1–c**	**1–d**	**1–e**
Inspectors	Multiple R	0.558	0.5085	0.5576	−0.751	−0.504
	Sig–F	0.0161	0.0312	0.0162	0.000328	0.0329
Expert	Multiple R	0.1199	0.0742	−0.0473	−0.0421	−0.0032
	Sig–F	0.00004	0.0117	0.1085	0.1534	0.9142
		2–a	**2–b**	**2–c**	**2–d**	**2–e**
Inspectors	Multiple R	0.0011	0.4609	0.4067	−0.1825	−0.5178
	Sig–F	0.9965	0.0542	0.0939	0.4686	0.0277
Expert	Multiple R	0.0023	0.2509	0.1995	−0.2141	−0.2144
	Sig–F	0.9372	5.1538 x 10^{-18}	8.143 x 10^{-12}	2.0152 x 10^{-13}	1.8678 x 10^{-13}
		3–a	**3–b**	**3–c**	**3–d**	**3–e**
Inspectors	Multiple R	−0.4156	−0.5935	−0.5563	0.6475	0.5719
	Sig–F	0.0863	0.0094	0.0165	0.0037	0.01314
Expert	Multiple R	−0.0246	−0.267	−0.1926	0.2239	0.217
	Sig–F	0.4044	2.843	4.2676 x 10^{-11}	1.4464 x 10^{-14}	9.433 x 10^{-14}
		4–a	**4–b**	**4–c**	**4–d**	**4–e**
Inspectors	Multiple R	−0.195	−0.3663	−0.3376	0.0758	0.6266
	Sig–F	0.438	0.1349	0.1706	0.765	0.0054
Expert	Multiple R	0	0	0	0	0
	Sig–F	0	0	0	0	0
		5–a	**5–b**	**5–c**	**5–d**	**5–e**

		0–a	0–b	0–c	0–d	0–e
Inspectors	Multiple R	−0.0856	−0.1657	−0.1508	0.1393	0.1759
	Sig–F	0.7356	0.511	0.5502	0.5814	0.485
Expert	Multiple R	0	0	0	0	0
	Sig–F	0	0	0	0	0

The evaluation results indicate that the Non-Physical and Physical assessment methods exhibit a positive correlation, as reflected in the generally linear relationship between the two sets of condition ratings. However, notable rating biases remain, primarily arising from differences in how each method defines the degree and extent of damage. These discrepancies warrant continued attention, as they influence the consistency of assessments across different damage types.

The correlation values derived from this analysis serve as a critical foundation for the subsequent phase of the research. In the next stage, condition evaluations will be performed on 30 bridge samples, 15 concrete-girder bridges and 15 steel-girder bridges, using the established correlation framework. This approach is expected to support a more robust, consistent, and objectively calibrated assessment process.

5.2.2 Outcomes of Bridge Condition Inspections

In this study, 30 simply supported bridges located on the National Road in East Java, Indonesia, were selected. The selection was based on the type of super-structure, specifically reinforced concrete girders, prestressed concrete girders, steel girders, and the types of damage observed, such as cracking, corrosion of the reinforcing steel, spalling, coatings, and corrosion of the steel girders. Additionally, the ease of access for inspection team to the locations was considered, and the presence of heavy traffic conditions.

Visual inspections of these 30 bridges were conducted using the applicable bridge inspection guidelines in Indonesia. Additionally, the bridge conditions were assessed according to the assessment guidelines in Japan to determine whether there are differences between non-physical assessment methods with Indonesian inspection guidelines and the conversion between non-physical to physical assessment according to the previous perception alignment analysis results and physical assessment methods with Japanese inspection guidelines. The results of the bridge inspections can be seen in Table 5-10.

Table 5-10. Segmentation of 30 bridges based on non-physical (NP) and physical (P) assessment on the National Road in East Java, Indonesia.

No	Bridge Code	Number of Span	Number of Girder	NP1 (1 Segment)	P2 (2 Segment)	P3 (3 Segment)	P4 (4 Segment)	P6 (6 Segment)
1	1-C	1	8	8	16	24	32	48
2	2-C	3	12	12	24	36	48	72
3	3-C	1	8	8	16	24	32	48
4	4-C	5	50	50	100	150	200	300
5	5-C	1	6	6	12	18	24	36
6	6-C	1	6	6	12	18	24	36
7	7-C	1	16	16	32	48	64	96
8	8-C	1	17	17	34	51	68	102
9	9-C	1	16	16	32	48	64	96
10	10-C	1	17	17	34	51	68	102
11	11-C	2	12	12	24	36	48	72
12	12-C	1	5	5	10	15	20	30
13	13-C	1	5	5	10	15	20	30
14	14-C	1	6	6	12	18	24	36
15	15-C	1	6	6	12	18	24	36
16	1-S	1	6	6	12	18	24	36
17	2-S	1	13	13	26	39	52	78
18	3-S	2	14	14	28	42	56	84
19	4-S	3	30	30	60	90	120	180
20	5-S	1	18	18	36	54	72	108
21	6-S	1	21	21	42	63	84	126
22	7-S	1	19	19	38	57	76	114
23	8-S	1	25	25	50	75	100	150
24	9-S	1	8	8	16	24	32	48
25	10-S	1	19	19	38	57	76	114
26	11-S	1	19	19	38	57	76	114
27	12-S	1	13	13	26	39	52	78
28	13-S	1	13	13	26	39	52	78
29	14-S	1	6	6	12	18	24	36
30	15-S	1	18	18	36	54	72	108

Based on Table 5-10, the LCCA results for the 30 bridge samples can now be calculated using the iBMS application. At first glance, the conversion from non-physical to physical assessment tends to yield worse condition ratings. However, it is important to note the differences in the detailed damage area distribution between the elements assessed by the non-physical and physical methods. Additionally, there are differences in the evaluation approach between the two methods: the non-physical method always assigns the worst condition for an element, while the physical method determines the condition based on the specific location of the damage in each segment. Subsequently, the non-physical assessment results are converted to physical assessments based on the correlation study findings. From this damage distribution, the LCCA will be calculated using the iBMS application. This will reveal which method yields more optimal results for implementation in the Bridge Management System in Indonesia, particularly for bridges on national roads.

High-Precision LCCA, which is a significant advantage of the iBMS application, demonstrates the extent to which an element needs to be detailed to achieve optimal results. Therefore, this study will compare the results of the non-physical and physical methods to determine the best LCCA optimization for implementation in the Bridge Management System in Indonesia.

5.2.3 Optimization of Lifecycle Costs Using HP-LCCA

To determine the total Life Cycle Cost (LCC), several supporting data points are required, which serve as assumptions in calculating the total repair costs needed for the iBMS application. One of these supporting data points is the repair cost per square meter for various types of repair methods, as shown in Table 5-11. These costs are the figures listed in the iBMS application, corresponding to the average repair requirements in Japan, and have been manually converted using an exchange rate of 100 IDR/YEN. The use of area measurements in this calculation is based on field inspection data, as well as the maintenance planning incorporated in the iBMS application, which utilizes area-based units of measurement.

Table 5-11. Estimated repair cost per square meter in IDR.

No.	Repair Method	Cost IDR/m^2
1	Chloride Removal from Concrete (Electrochemical Desalination)	IDR 9,000,000
2	Sectional Repair	IDR 6,500,000
3	Surface Impregnation	IDR 1,300,000
4	Cathodic Protection	IDR 9,500,000
5	Surface Coating	IDR 1,000,000
6	Crack Injection	IDR 1,000,000
7	Replacement	IDR 40,000,000
8	Do Nothing	IDR-

The analysis results using the iBMS application reveal several LCCA outcomes that show differences between bridges inspected using the non-physical (NP) and physical (P) methods, as illustrated in Table 5-12. There are discrepancies in the Condition States (CS) between the NP and P methods, including the number of segments with damage such as cracking, rebar corrosion, spalling, steel coatings, and corrosion. These differences will affect the amount of maintenance required, thereby impacting the total cost. The difference in total costs may be attributed to the varying levels of damage and the distribution of damages present. As observed in the non-physical assessment, the evaluations tend to be worse compared to those of the physical assessment.

Table 5-12. Results of data analysis for 30 bridges with non-physical and physical methods using the iBMS application.

Bridge Code	1 Segment Non-Physical	2 Segment Physical	3 Segment Physical	4 Segment Physical	6 Segment Physical
Bridge 1C	7,081.23	7,172.02	7,202.28	7,217.41	7,232.55
Bridge 2C	3,400.00	3,400.00	3,400.00	3,400.00	3,400.00
Bridge 3C	4,959.30	4,959.30	4,959.30	4,959.30	4,959.30
Bridge 4C	5,204.94	5,204.94	5,464.16	5,464.17	5,464.16

Bridge Code	1 Segment Non-Physical	2 Segment Physical	3 Segment Physical	4 Segment Physical	6 Segment Physical
Bridge 5C	1,020.00	1,020.00	1,020.00	940.99	914.66
Bridge 6C	3,901.50	3,427.73	3,269.81	3,072.40	2,953.97
Bridge 7C	4,620.21	4,492.70	4,407.69	4,365.19	4,333.31
Bridge 8C	1,198.50	1,198.50	1,198.50	1,198.50	1,207.00
Bridge 9C	4,210.41	4,141.84	4,118.99	4,107.56	4,097.77
Bridge 10C	2,774.40	2,236.77	1,788.90	1,675.40	1,614.04
Bridge 11C	5,767.77	5,348.80	4,733.54	4,720.36	4,510.88
Bridge 12C	1,281.79	1,281.79	1,281.79	1,281.79	1,281.79
Bridge 13C	1,806.08	1,066.24	819.63	696.32	757.97
Bridge 14C	961.97	641.35	401.03	360.80	267.28
Bridge 15C	2,968.00	1,969.33	1,503.29	1,270.27	1,103.82
Bridge 1S	694.52	694.52	694.52	694.52	694.52
Bridge 2S	459.53	518.59	518.59	518.59	518.59
Bridge 3S	1,522.36	1,522.36	1,522.36	1,522.35	1,522.35
Bridge 4S	71.53	71.52	71.31	71.65	71.70
Bridge 5S	31.29	31.29	31.29	31.29	31.29
Bridge 6S	46.94	46.94	46.94	46.94	57.11
Bridge 7S	12.38	12.38	12.38	12.38	12.07
Bridge 8S	13.68	13.68	13.68	13.68	13.68
Bridge 9S	33.65	33.65	33.65	33.65	33.65
Bridge 10S	156.62	156.62	156.62	156.62	183.70
Bridge 11S	262.13	262.13	221.29	194.88	164.15
Bridge 12S	123.87	108.20	108.20	108.20	108.20
Bridge 13S	42.29	42.29	42.29	42.29	42.29
Bridge 14S	484.04	484.04	484.04	484.04	484.04
Bridge 15S	133.67	133.67	200.31	115.73	114.31

* million Indonesian Rupiah (IDR).

Figure 5-12 shows that nine concrete-girder bridges achieved LCC optimization following segment division, with eight bridges reaching optimal values at six segments and one bridge at four segments. However, in three cases, segmentation led to increased LCC values. This occurred because certain segments received lower condition ratings—particularly grade "e"—after the division process. The reduction in segment-level condition scores subsequently increased the predicted deterioration probabilities, which in turn elevated the estimated repair costs.

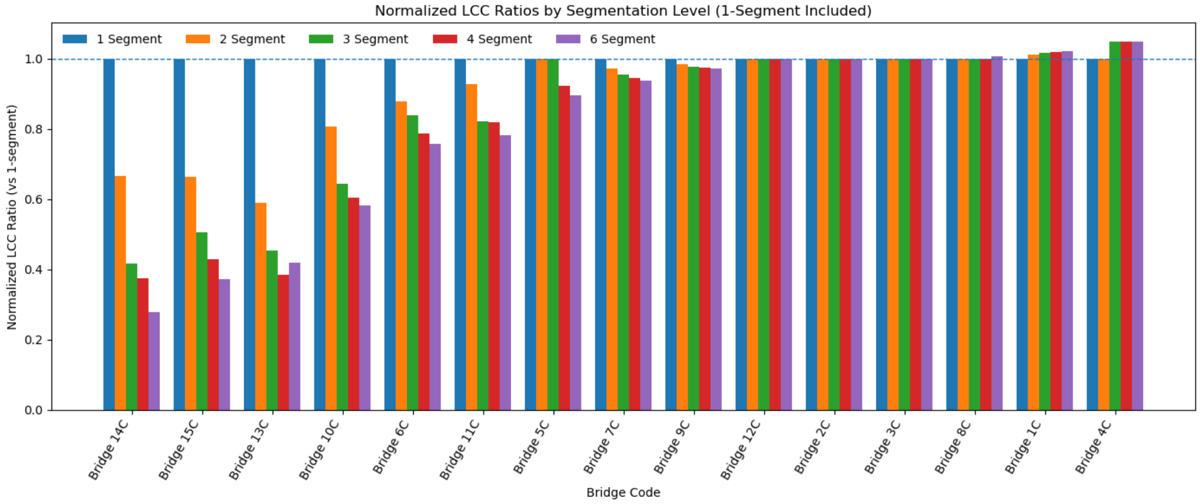


Figure 5-12. Normalized LCC ratio comparison with segment division for each concrete bridge

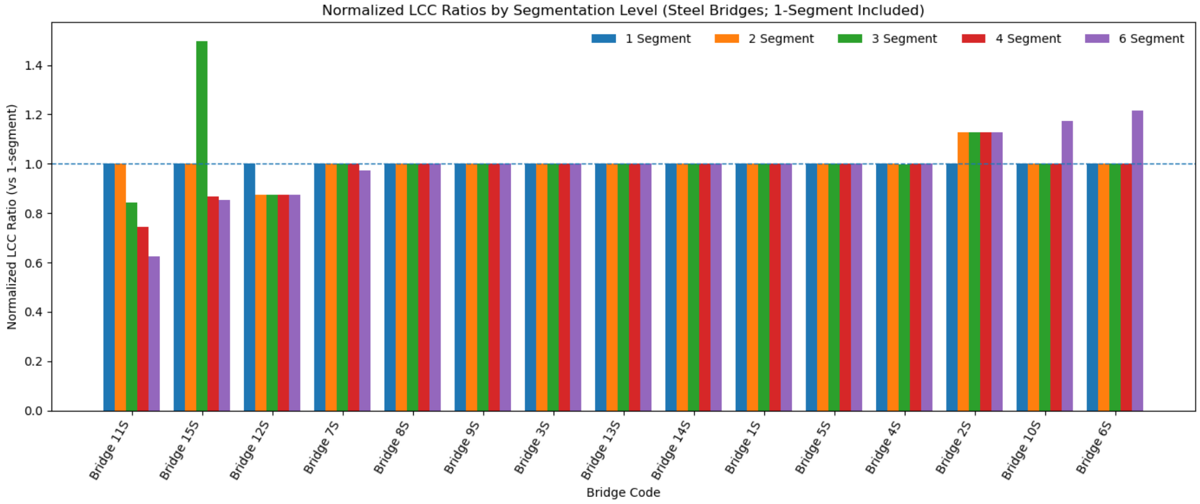


Figure 5-13. Normalized LCC ratio comparison with segment division for each steel bridge

In contrast, the LCC results for steel girders show a markedly different pattern as shown in Figure 5-13. Only four bridges experienced LCC optimization: three at the six-segment division and one at the two-segment division. For the remaining eleven bridges, no optimization occurred because the condition ratings across segments were largely uniform. This uniformity is likely attributable to the characteristic deterioration behavior of steel girders—such as widespread coating degradation and corrosion—which typically affects the steel surface more uniformly than localized concrete damage.

Based on the LCC calculations performed for the 30 bridges, the LCC values obtained using the Physical method were compared with those from the Non-Physical method by computing their ratios. This comparison was conducted to determine whether the applied segmentation resulted in a lower, and thus optimal, LCC value. Table 5-13 presents the optimal segmentation outcomes and the minimum LCC values derived from these calculations.

Table 5-13. The amount of savings for the application of segmentation with Physical and Non-Physical evaluation methods.

Bridge Code	Best Segmentation	Ratio	Savings (%)	Category
14C	6	0.278	72.22	Strong
15C	6	0.372	62.81	Strong
13C	4	0.386	61.45	Strong
10C	6	0.582	41.82	Strong
11S	6	0.626	37.38	Strong
6C	6	0.757	24.29	Moderate
11C	6	0.782	21.79	Moderate
15S	6	0.855	14.49	Moderate
12S	4	0.874	12.65	Moderate
5C	6	0.897	10.33	Moderate
7C	6	0.938	6.21	Mild
9C	6	0.973	2.68	Mild
7S	6	0.975	2.53	Mild
4S	3	0.997	0.3	Flat
8S	4	1	0	Flat
9S	6	1	0	Flat
1S	3	1	0	Flat
3S	6	1	0	Flat
5S	1	1	0	Flat
13S	1	1	0	Flat
12C	6	1	0	Flat
2C	4	1	0	Flat
8C	4	1	0	Flat
4C	2	1	0	Flat
3C	3	1	0	Flat
1C	1	1	0	Flat
14S	3	1	0	Flat

Bridge Code	Best Segmentation	Ratio	Savings (%)	Category
2S	1	1.1286	-12.8	Flat
10S	1	1.173	-17.2	Flat
6S	1	1.2175	-21.7	Flat

To quantify the effects of segmentation, LCC savings were classified into four categories: Strong (>30%), Moderate (10–30%), Mild (2–10%), and Flat (<2%). Among the 30 analyzed bridges, five fell into the strong category, five into the moderate category, three into the mild category, and the remaining fourteen into the flat category. Bridges in the strong-savings group exhibited substantial variation in condition ratings across segments. This variability allowed damage to be captured in a more localized manner, resulting in smaller damaged areas per segment and ultimately yielding substantial reductions in LCC. In contrast, bridges categorized as flat generally showed uniform condition ratings across all segments, meaning that segmentation did not reduce the LCC. Furthermore, three bridges exhibited higher LCC values after segmentation. This outcome likely occurred because certain segments received lower condition ratings after division, leading to higher predicted deterioration rates and consequently higher preservation costs.

Table 5-13 shows that the highest optimization value, 72.22%, occurred in Bridge 14C under the six-segment Physical method. This outcome demonstrates that detailed segmentation enhances condition assessment accuracy by isolating undamaged portions and reducing overestimation of deterioration. Conversely, bridges with uniformly distributed damage showed limited optimization potential. These results indicate that greater variability in condition ratings across segments increases the potential for achieving lower LCC values through optimized segmentation.

When examined by material type, concrete girders show a substantially greater likelihood of achieving minimum LCC values compared with steel girders. This difference is likely driven by the contrasting patterns of deterioration across the two materials. Field inspection results indicate that damage such as cracking, delamination, exposed reinforcement, and spalling rarely occurs uniformly across the entire concrete girder; instead, it tends to appear in localized areas. In contrast, deterioration in steel girders, particularly coating degradation and corrosion, typically develops simultaneously and uniformly across large surface areas. This fundamental difference in damage distribution means that LCC optimization through segmentation is more effective for concrete girders than for steel girders.

Further explanation for why concrete girders tend to produce optimal minimum LCC values is illustrated in Figure 5-14. The example of the segmented assessment for Girder No. 6 of Bridge 14C shows how localized variations in condition ratings produce distinct deterioration curves for each segment. By capturing these spatial differences, the iBMS system is able to model deterioration progression at a finer resolution, resulting in more accurate calculations and enabling the identification of truly minimum LCC values.

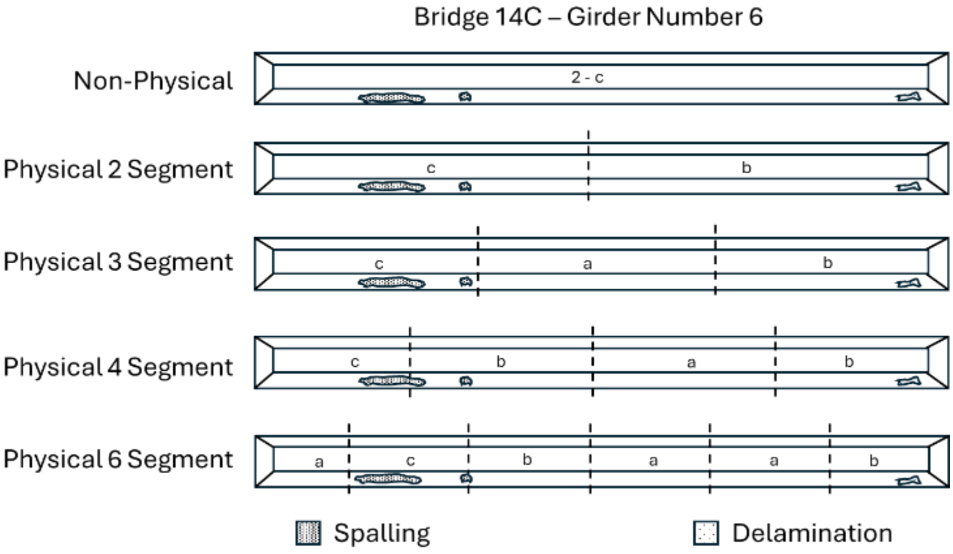


Figure 5-14. Illustration of the variation in condition assessment results for each girder segment

Furthermore, because concrete girders are more likely to achieve minimum LCC values, it is important to examine the relationship between the average LCC and the number of segments in order to identify the segmentation level that yields the lowest cost outcome. Figure 5-15 presents the LCC results for concrete girders show a maximum reduction of 7.04% (from 1 segment to 2 segments) and the smallest reduction of 1.34% (from 4 segments to 6 segments), due to variations in damage among segments. In contrast, steel girders do not show a significant reduction because the damage condition is relatively uniform across all segments.

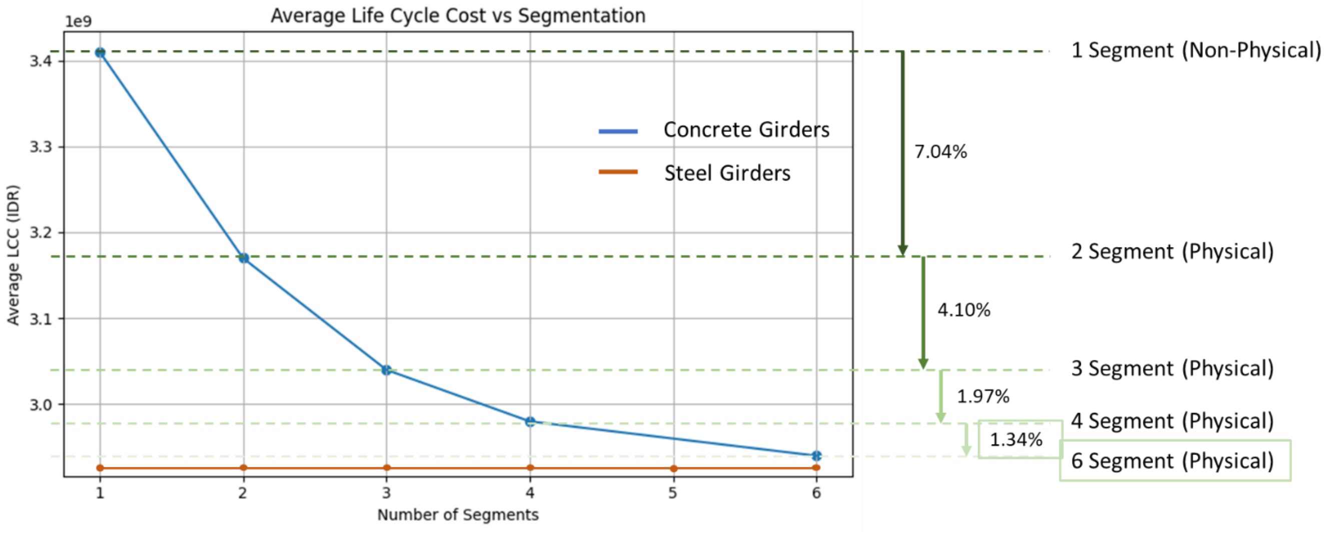


Figure 5-15. Average LCC comparison with segment division for each girder

Overall, segmentation in bridge condition assessment significantly enhances LCC precision and cost efficiency. For most bridges analyzed, the six-segment Physical evaluation provided the most consistent optimization results, aligning with the High-Precision Life Cycle Cost Analysis (HP-LCCA) framework. This approach supports data-driven, detailed, and cost-effective maintenance planning, representing a key advancement toward sustainable bridge asset management in Indonesia.

5.3 Critical Evaluation of HP-LCCA Implementation

Based on the analysis of the relationship between the Non-Physical and Physical assessments, a 77% similarity was observed in the evaluation patterns of the 13 concrete girder damage images. This high level of agreement indicates that both assessment methods tend to classify deterioration in concrete elements in a consistent manner. However, the remaining 33% of evaluations exhibit divergent patterns, suggesting the presence of potential bias or misinterpretation in either the Non-Physical or Physical assessments. In contrast, a notably different outcome was observed for the steel girders. The level of assessment objectivity was considerably lower, with only 56% of the evaluations showing consistent patterns between the two methods. This reduced alignment highlights greater variability and potential subjectivity in the condition assessment of steel girders compared with concrete elements.

This can be attributed to the low objectivity in both types of assessments. In this study, the respondents are generally experienced bridge inspectors, which suggests that the damage images presented may have multiple interpretations, potentially leading to errors. Overall, it can be concluded that non-physical and physical assessments tend to follow similar evaluation patterns.

Assessments with multiple interpretations are particularly evident in the Non-Physical evaluations, especially for condition ratings “1” and “2.” These two categories exhibit a wide range of interpretations among inspectors in Indonesia, requiring bridge owners to carefully review condition assessments performed in the field. A similar pattern is also present in the Physical assessments, where these same ratings show considerable variability in interpretation.

However, questionnaire statistics for concrete girders indicate that condition states “0” and “1” display substantial bias, with correlations ranging broadly from “a” to “c.” In contrast, for steel girders, the bias occurs primarily in condition states “1” and “2,” which correlate variably with categories “a” through “c.” Furthermore, condition state “3” shows a clear and consistent correlation with “d” for concrete girders, whereas for steel girders, this state displays a rating bias between “d” and “e.” Finally, for condition states “4” and “5,” both girder types exhibit more uniform and consistent assessment outcomes.

Due to this subjectivity and the inherent potential for misclassification within these rating ranges, the observed condition of a bridge element may be evaluated as either better or worse than its actual condition in the field. This highlights the importance of improving assessment criteria and strengthening inspector calibration to reduce variability and enhance reliability in bridge condition evaluations.

Between the non-physical and physical assessments, there are also instances of negative correlations, indicating a lack of a strong relationship between the two variables. This is evidenced by the minimal population of values within these negative correlations, suggesting that the relationships producing negative values do not have significant correlations.

A closer examination of the types of damage assessed reveals that cracking is one of the primary sources of assessment error among bridge inspectors. Distinguishing between non-structural and structural cracks is challenging, even for experienced inspectors, because cracks often appear visually similar despite arising from different mechanisms. Certain cracks result from localized high-stress concentrations, while others originate from reinforcement corrosion, which causes internal expansion and produces characteristic cracking patterns. Although shrinkage cracks can generally be recognized based on their surface patterns, wider cracks often prompt inspectors to assign more severe condition ratings, even when the underlying causes differ.

In the evaluation of steel girders, several assessments were also inconsistent with the validated expert results. Such discrepancies likely stem from limited information or insufficient understanding of steel deterioration processes. While differentiating between intact steel surfaces and those exhibiting coating deterioration or corrosion is relatively straightforward, accurately determining the severity of these defects requires more advanced experience and technical knowledge.

These findings underscore the need for clearer and more detailed assessment criteria to better distinguish the severity levels of both concrete and steel deterioration. Strengthening these criteria will enable inspectors to conduct condition evaluations more objectively and reduce variability in the assessment process.

Errors in inspection results, according to the objectivity assessment study, range between 31% and 43%. This should be a point of concern for bridge managers, indicating the need for a larger sample size when validating bridge condition data in the future. This validation is crucial to anticipating assessment errors in bridge inspection reports, which can significantly impact the planning of bridge maintenance programs. To enhance the objectivity of condition assessments in the future, several measures can be implemented, including conducting regular training for bridge inspectors. Additional specialized tools such as crack meters or hammers is needed to accurately determine the severity of damage.

Based on the expert evaluations, the correlation between the Non-Physical and Physical assessment methods for both girder types demonstrates considerably higher objectivity. These findings reaffirm that professional experience plays a critical role in improving the accuracy and precision of condition assessments, enabling experts to produce evaluations that more closely reflect the actual deterioration observed in the field.

Despite this, both the questionnaire-based assessments conducted by field inspectors and the expert evaluations derived from reviewing visual inspection data show the presence of rating biases. The underlying causes of these biases cannot be fully understood without deeper investigation. To address this issue, detailed correlation analysis for each damage type becomes essential. Evaluations conducted across six damage types—cracking, delamination, exposed reinforcement, spalling, coating deterioration, and corrosion—reveal a consistent and notable phenomenon: the Non-Physical and Physical assessment methods rely on fundamentally different criteria, particularly with respect to defining the degree and extent of damage.

These criteria differ not only in their thresholds but also in their underlying logic. For example, in the Non-Physical method, a minimum damage quantity is recognized only when the affected area exceeds 30%, whereas the Physical method sets a higher threshold at 50%. Similarly, the two methods define minimum crack-width thresholds differently, leading to divergent ratings for the same observed condition.

Such discrepancies highlight the need to refine the evaluation process. Segmenting the assessed elements offers a practical approach to reducing bias, as it allows the criteria—especially those related to damage extent—to be applied more objectively and consistently across localized areas of deterioration.

In the optimization of LCC calculations, Non-Physical evaluations of 30 bridges were converted into segmented Physical assessments to enhance diagnostic precision. Nine bridges exhibited changes in condition ratings after segmentation, with thirteen achieving lower Life Cycle Cost (LCC) values: five categorized as strong (> 30 %), five as moderate (10–30 %), three as mild (2–10 %), and the remaining fourteen showing no reduction. Bridges in the strong category exhibited greater variability in segment-level ratings, confirming that detailed segmentation improves accuracy by capturing localized deterioration. Conversely, bridges with uniformly distributed damage exhibited minimal rating variation and negligible cost reduction. The highest optimization value, 72.22 %, occurred in Bridge 14C using six-segment division, which improved diagnostic accuracy by distinguishing minor defects from severe deterioration. This segmentation produced more objective and spatially representative condition data, significantly reducing LCC and bias from generalized evaluations.

Regression analysis further indicates that dividing bridge elements into six segments provides the optimal balance between analytical precision and practicality. The six-segment Physical evaluation consistently produced the lowest LCC values, confirming its superior performance in achieving cost optimization. Overall, the findings demonstrate that the precision of condition assessment is directly proportional to the attainment of minimum LCC values. Greater segmentation detail enhances objectivity, improves deterioration modeling, and supports data-driven maintenance planning. Although the Non-Physical method can also produce reliable results when segmentation is applied, the segmented Physical evaluation remains the most effective for accurate LCC estimation and cost-efficient bridge management.

5.4 Summary of HP-LCCA Findings

The objective of the research conducted was to compare the non-physical and physical assessment methods by conducting a questionnaire survey among bridge inspectors. Correlation analysis was employed to determine the relationship between the two variables. Additionally, Life Cycle Cost (LCC) calculations were performed using the iBMS application to find the optimal values for both assessment methods.

Based on the research findings, it can be concluded that, overall, the non-physical and physical assessment methods exhibit similar condition rating patterns. Nevertheless, a small portion of these patterns remains insufficiently characterized due to limitations in the available data. The two methods differ fundamentally in how they define and evaluate the degree and extent of damage, which accounts for the discrepancies observed in a subset of the assessments. Despite these differences, the strong correlation between the two methods indicates that the non-physical assessment approach can be effectively utilized for High-Precision Life Cycle Cost Analysis (HP-LCCA) within the iBMS framework.

The comparison results between the non-physical and physical assessments indicate a significant difference. The physical method generally outperforms the non-physical method in Life Cycle Cost (LCC) calculations. The findings suggest that physical assessments can optimize the total cost required for bridge maintenance over its service life. This advantage is achieved through more detailed segmentation of structural elements, allowing for maintenance to be applied to smaller areas with varying condition predictions based on the condition state of each assessed element. Furthermore, the higher LCC associated with the non-physical method is primarily due to the application of maximum condition ratings, which contribute significantly to the overall cost.

Based on the research findings, several recommendations for implementing this application in Indonesia include the enhanced data detail to improve the detail of bridge inspection data, particularly at the individual structural element level. This enhancement can optimize the planning and scheduling of bridge preservation, helping to reduce the total repair cost according to the bridge’s service life. Furthermore, the condition model needs to be updated by incorporating reference models, such as Indonesia's chloride zoning, as a basis for future iBMS application development. These steps will contribute to more effective bridge management and cost optimization.

CHAPTER 6
DISCUSSION AND CONCLUSION

6.1 Integrated Discussion of Research Outcomes

In the current implementation of bridge asset management in Indonesia, two primary challenges are encountered: the asset management organization and the asset management system being utilized. Based on the findings of recent research, several noteworthy observations warrant further discussion. First, the implementation process of bridge asset management in Indonesia appears to be quite complex. It is therefore crucial to carefully identify the factors influencing organizations in adopting asset management practices. In addition to understanding these factors, concrete steps should be taken based on the recommendations derived from the research findings. Second, the asset management system employed plays a critical role in optimizing bridge maintenance costs to ensure greater effectiveness and efficiency. These two aspects form the foundation of this study, which aims to develop an optimization model tailored to meet specific needs.

Bridge asset management implementation in Indonesia involves asset managers distributed across multiple provinces. Strengthening these managers' intention to implement asset management is a central objective of this research. Previous studies have shown that several factors significantly shape managers' intention to implement asset management, including budget availability, data quality, policy support, human resources, and the robustness of the management system. Based on the regression analysis conducted in this study, strong relationships were identified between several of these factors and asset managers' implementation behavior. These findings were further corroborated by interviews with senior managers and deepened through Qualitative Comparative Analysis (QCA) to determine the most effective solution configurations for implementing bridge asset management.

The regression analysis indicates that perceived behavioral control significantly supports asset managers' intention, with a standardized coefficient of $\beta^* = 0.574$ and $p < 0.001$, demonstrating a strong association between the two variables. This finding suggests that asset managers' willingness to implement asset management is closely linked to perceived behavioral control, which captures their confidence in their capacity to manage bridge assets effectively. To clarify which implementation behaviors require control, it is therefore necessary to examine in greater detail the factors that shape asset managers perceived behavioral control.

Perceived behavioral control was largely explained by the adequacy of budget provision ($\beta^* = 0.258$, $p < 0.001$), the reliability of asset data ($\beta^* = 0.258$, $p < 0.001$), and the availability of supporting resources ($\beta^* = 0.276$, $p = 0.001$). Collectively, these results indicate that budget, data quality, and resources strengthen asset managers' confidence and capacity to carry out bridge asset management implementation.

Therefore, encouraging bridge asset managers to adopt a new asset management system should prioritize strengthening perceived behavioral control through three key determinants: budget availability, data quality, and resource capacity. Adoption is more likely when a clearly allocated and accessible budget is provided to support initial implementation needs, when asset data meet consistent minimum standards and are systematically validated to ensure that system outputs are credible, and when sufficient human and operational resources with trained personnel, role allocation, and implementation support, are in place so managers feel capable of executing the required procedures. When these three conditions are satisfied, implementation barriers are reduced, managerial confidence increases, and intention to adopt the new system becomes substantially stronger.

The regression results presented earlier are also supported from the experts' perspective. Across the interviews, data quality and human resources were repeatedly emphasized as critical determinants of successful asset management implementation. Experts further noted that Indonesia’s asset management policy framework remains insufficiently articulated, as evidenced by unclear managerial responsibilities and the absence of standardized qualification requirements for asset managers. Several experts additionally identified budget constraints as an important implementation bottleneck. Overall, these insights corroborate the quantitative findings and provide complementary qualitative evidence. Nevertheless, further clarification is needed to identify the most effective solution configurations across the relevant variables that jointly enable successful bridge asset management implementation.

A closer examination of the QCA results indicates that managers’ intention is shaped by a specific configuration of four conditions—data quality, the management system, attitude, and perceived behavioral control—with a solution consistency of 0.937 and raw coverage of 0.716. This finding suggests that successful bridge asset management implementation can be achieved by ensuring validated, reliable data and a user-friendly management system, which together foster positive managerial attitudes and strengthen managers’ confidence in their ability to execute asset management tasks effectively.

As illustrated in Figure 6-1, the three analytical approaches—Theory of Planned Behavior (TPB), expert interviews, and Qualitative Comparative Analysis (QCA)—converge on a consistent set of enablers for effective bridge asset management implementation. Data quality emerges as the most influential factor, shaping asset managers’ attitudes and perceived behavioral control, as indicated by both the TPB and QCA findings. This result is corroborated by the expert interviews, which identify inadequate data quality as a persistent constraint in Indonesia’s current practice. A second cross-cutting theme concerns human resource capacity and its distribution: both TPB and QCA highlight resource adequacy as critical, while experts emphasize that existing capacity remains unevenly distributed, particularly in regional agencies. Finally, QCA identifies the management system as a key barrier that must be addressed to support implementation. This aligns with TPB and interview evidence indicating that the current tool lacks the analytical sophistication needed to optimize resource allocation, often biasing budgets toward corrective maintenance at the expense of preventive strategies.

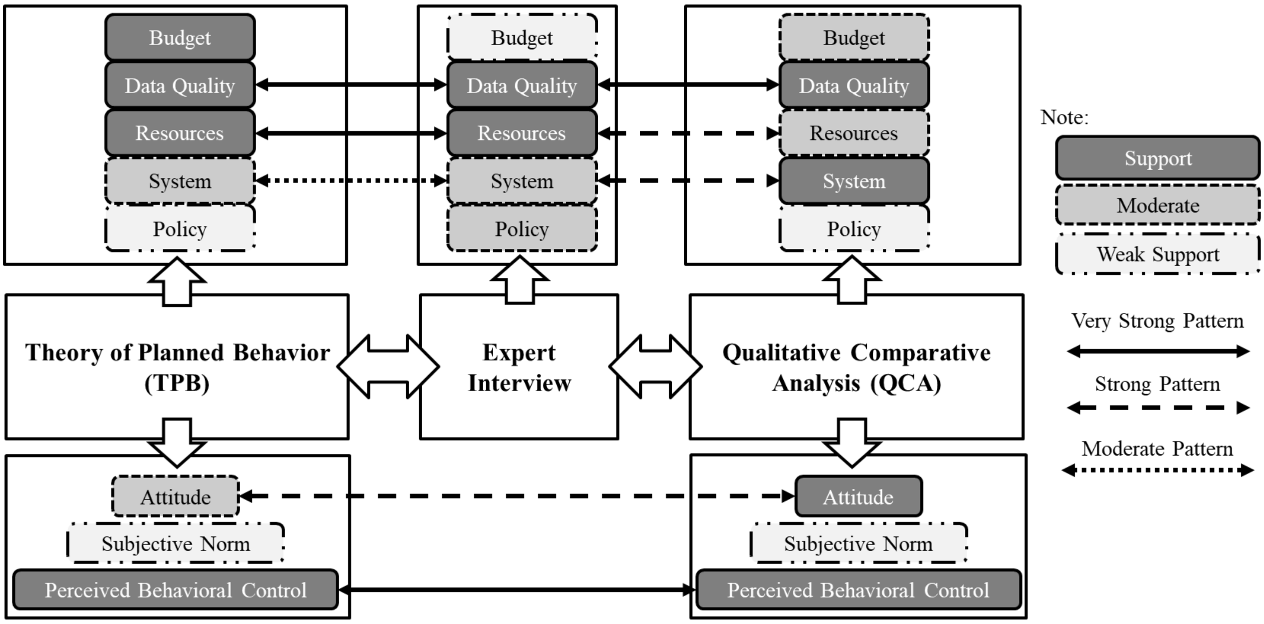


Figure 6-1. The results of the TPB, QCA, and expert interview analyses reveal mutually reinforcing patterns that strengthen the overall conclusions.

Given that the QCA configurations align with both the multiple regression results and expert perspectives, the convergence of these three lines of evidence is summarized in Figure 6-1. Collectively, the findings indicate that data quality is the primary driver underpinning managers perceived behavioral control to implement bridge asset management effectively. In addition, budget availability remains a salient consideration for asset managers; therefore, organizations should ensure adequate and stable funding to support implementation. By contrast, policy has not yet emerged as a factor that directly strengthens managers' intention to adopt bridge asset management, despite being repeatedly emphasized by experts. Accordingly, policy reforms are necessary to institutionalize asset management as a strategic priority and to provide a clearer enabling environment for asset managers to implement bridge asset management in a sustained and effective manner.

Moreover, both the TPB and QCA results reveal a similar pattern: asset managers perceived behavioral control, and attitudes significantly support their intention to implement bridge asset management. Among these two determinants, perceived behavioral control emerges as the strongest driver motivating managers to adopt asset management practices. Accordingly, strengthening enabling conditions—particularly improving data quality and ensuring adequate human resources—becomes essential for promoting implementation. In parallel, managers' attitudes are strongly reinforced by the availability of reliable, high-quality data, making data improvement a second critical priority for advancing bridge asset management implementation in Indonesia.

Regarding the "resources" factor identified in the multiple regression analysis, the findings indicate underlying issues that require more detailed explanation. The QCA results further specify that the key qualifications for bridge asset management personnel are professional certification and relevant experience. However, this ideal profile is not consistently present within the National Road Agency, suggesting a need to strengthen the capacity of regional asset managers through targeted training programs and structured technical discussions. Such capacity-building efforts are essential to promote more uniform and effective implementation of bridge asset management across all regions.

Implementing a new asset management system is expected to improve the accuracy of calculations used to determine a bridge's life-cycle cost (LCC), a widely applied approach for estimating the total costs incurred from construction through replacement or decommissioning. Given that data quality is the most critical factor supporting asset managers in implementing asset management, it is essential to prepare reliable and validated data. One practical approach to strengthening data reliability is to conduct a correlation analysis between two different condition assessment methods. At present, Indonesia primarily applies a Non-Physical evaluation method, whereas the proposed system is based on a Physical evaluation method.

The correlation results will therefore determine which assessment approach should be adopted and which criteria require clarification to enable the effective implementation of the Intelligent Bridge Management System (iBMS) for bridge asset management in Indonesia.

This study demonstrates that the new model correlation between Physical and Non-Physical bridge condition evaluation methods can be systematically established to enhance the accuracy of Life Cycle Cost (LCC) estimation. A generally linear relationship was identified between the two approaches, variations in damage quantity and extent were found to significantly affect the objectivity of the assessments. Two distinct correlation probabilities emerged, reflecting methodological differences in defining damage extent, differences that diminish when segmentation is applied. These results confirm that increasing assessment detail improves evaluation objectivity and enhances the reliability of cost predictions.

The Non-Physical evaluation method produces a single condition datum for each bridge, which is then used to compute the life-cycle cost (LCC) for the structure as a whole. Consequently, transforming these results into the Physical evaluation framework requires a more detailed correlation approach, so that each subdivided segment can be assigned its own deterioration model that reflects the specific damage type and severity observed. The Transition Probability Matrix (TPM) analysis indicates that the Nature Mark (S) consistently co-occurs with the presence of structural damage in the assessed element. In contrast, the Degree Mark (R) and Extent Mark (K) generate two distinct deterioration pathways, reflecting differences in criteria between the Non-Physical and Physical assessment methods. For conservative decision-making, the more severe deterioration pathway should be adopted, as it provides a safer structural basis and better represents the overall condition of the element.

To provide a brief overview of the relationship between the Non-Physical and Physical assessment methods, Figure 6-2 illustrates the correspondence between their condition ratings.

The figure indicates that Non-Physical condition state “0” consistently shows a positive correlation with Physical rating “a”. Condition states “1” and “2” generally correspond to rating “b”. However, condition state “2”, together with condition state “3”, also exhibits correlation with rating “d”. This pattern suggests that condition states “2” and “3” in the Non-Physical method may follow two alternative deterioration pathways—toward ratings “b” and “d”. Accordingly, the severity of damage (R) and damage extent (K) criteria require clearer and more detailed definitions to better accommodate the classification scheme used in the Physical method.

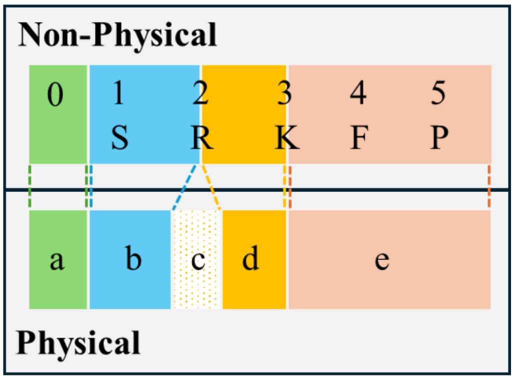


Figure 6-2. The correlation between the Non-Physical and Physical criteria.

The figure also shows that Physical rating “e” spans a broad range of Non-Physical condition states (“3”, “4”, and “5”), indicating substantial subjectivity in this mapping. In practice, this implies that the “F” and “P” criteria in the Non-Physical evaluation represent critical or non-functional element conditions. Under such critical or non-functional states, Life Cycle Cost (LCC) optimization is not feasible; therefore, meaningful optimization is limited to condition states “0” through “3”. In addition, Physical rating “c” did not demonstrate a sufficiently strong correlation with the corresponding Non-Physical condition states, likely due to bias that introduces a high degree of subjectivity in the evaluation process.

An appropriate solution to address this discrepancy is to revise the Non-Physical criteria for the S, R, and K marks so that they align more closely with the a–e rating scale used in the Physical evaluation method. As illustrated in Figure 6-3, a substantial gap remains, particularly in mapping the Physical rating "e" to the corresponding Non-Physical criteria. The Physical rating "e" spans a relatively broad correlation range, which increases the perceived subjectivity of the Non-Physical assessment; consequently, LCC optimization is not feasible for this condition, as the required maintenance interventions would be costly. Accordingly, it can be inferred that deterioration processes for which LCC outcomes can be meaningfully optimized are limited to Non-Physical condition levels 0 through 3.

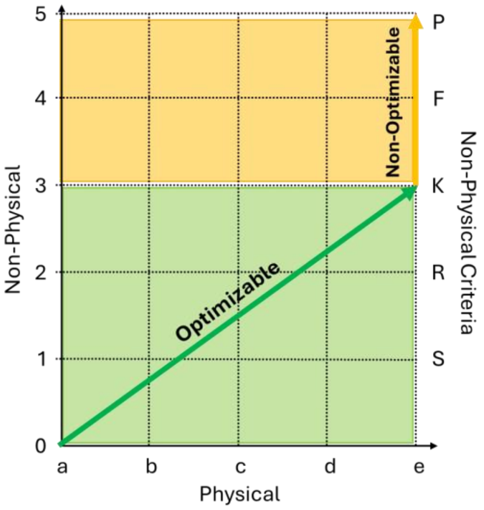


Figure 6-3. The correlation domain between the Non-Physical and Physical criteria that can be optimized for LCC analysis.

The results also demonstrate differences in deterioration behavior between concrete and steel girders. Concrete girders exhibit a relatively gradual decline in the early deterioration period, whereas steel girders show a more rapid deterioration in the initial stage. This pattern suggests that condition-rating subjectivity is more likely to arise for steel girders, because small errors in assigning early condition states can lead to substantial deviations in the inferred deterioration path. This interpretation is consistent with the condition-assessment questionnaire results, which likewise indicate reduced objectivity when evaluating steel girder elements. Therefore, condition assessment for steel girders is more prone to misinterpretation than for concrete girders. These findings imply that improving inspectors' early-stage assessments through clearer and more detailed guidelines could reduce subjectivity and support more reliable LCC outcomes.

As illustrated in Figure 6-4, the Non-Physical evaluation method assigns a single condition rating to each girder, which is assumed to represent the overall girder condition. This contrasts with the Physical evaluation method used in this study, which subdivides the girder into multiple segments, ranging from two to six. This segmentation is intended to capture localized damage, allowing condition levels to vary across segments. Such differences are expected to substantially influence the minimum life-cycle cost (LCC) that can be achieved.

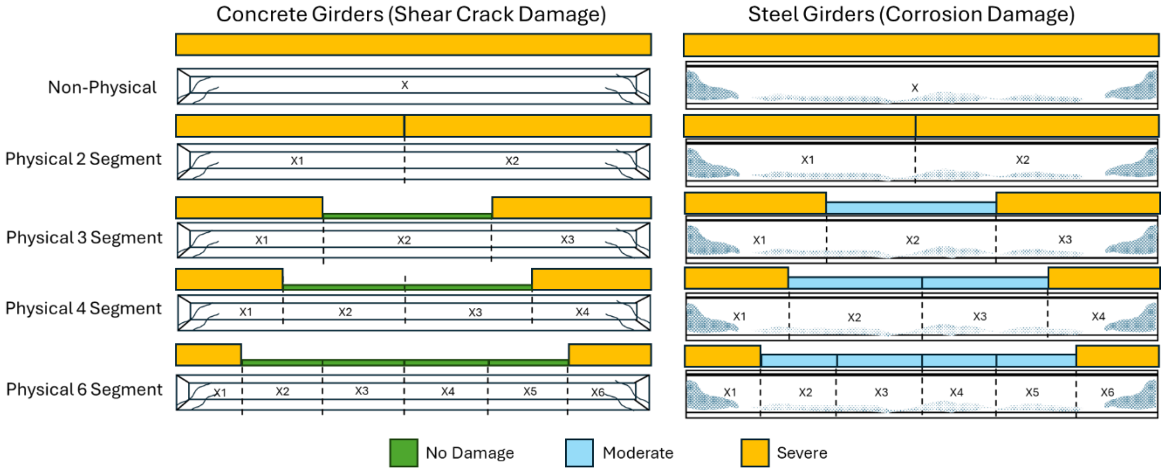


Figure 6-4. Bridge segmentation illustration for Non-Physical and Physical evaluation method.

The deterioration characteristics of concrete and steel girders also differ markedly. Damage in concrete girders tends to be localized, leading to greater variation in both damage severity and damage types among segments. In contrast, steel girders generally exhibit more uniform and widespread damage along the entire girder length. As a result, many steel girders do not achieve LCC reductions beyond the minimum levels attained for concrete girders.

Incorporating segmentation into the Physical evaluation framework substantially improves cost optimization by capturing the spatial heterogeneity of deterioration across structural elements. Under this approach, the minimum LCC values were achieved for bridges with concrete girders exhibiting non-uniform damage patterns, with LCC reductions of up to 72.2%. In contrast, steel-girder bridges, which showed relatively uniform deterioration across segments, offered more limited potential for additional optimization, with a maximum LCC reduction of 37.38%. Overall, most concrete-girder bridges (9 samples) experienced LCC reductions and showed considerable variation in segment-level condition ratings, reflecting differences in damage type and severity. By comparison, steel girders generally exhibited more evenly distributed deterioration across segments; only 4 out of 15 bridge samples showed LCC reductions, which diminished the effectiveness of segmentation-based optimization.

Segmenting the target girder element into six segments yielded the most optimal performance. This is evidenced by the diminishing marginal reduction in LCC for concrete girders, where the decrease between the four- and six-segment models was only 1.34%. In contrast, for steel girders, the optimization was not significant because deterioration was relatively uniform across the girder surface.

Overall, the segmented Physical evaluation method provides superior optimization performance, whereas the Non-Physical method remains effective when segmentation is applied. Introducing a new model that integrates adjusted correlation mapping and segmented assessments into bridge management systems enables more objective condition evaluations, more accurate LCC estimates, and data-driven maintenance planning. These findings support the broader adoption of High-Precision Life Cycle Cost Analysis (HP-LCCA), fostering more sustainable, cost-efficient, and adaptive bridge asset management practices, even in systems that currently rely on Non-Physical evaluation methods.

Figure 6-5 is presented to facilitate a clearer understanding of how the technical implementation issues in bridge asset management can be addressed. It synthesizes the full analytical workflow—ranging from the correlation model, deterioration process modeling, and deterioration path selection to LCC estimation—developed to support effective technical implementation in Indonesia. The figure illustrates that differences in condition assessment methods require adjustment through a correlation model before LCC calculations can be applied. The correlation results further reveal limitations in deterioration modeling, reflected in low accuracy when classifying damage criteria, particularly damage severity (R) and damage extent (K). To mitigate this low accuracy, two solutions are proposed: (1) selecting an accurate risk-based deterioration path that reflects the observed damage conditions, and (2) applying segmentation to the assessed structural element. These interventions form the proposed new model, which is expected to improve accuracy and, consequently, enable the achievement of minimum LCC.

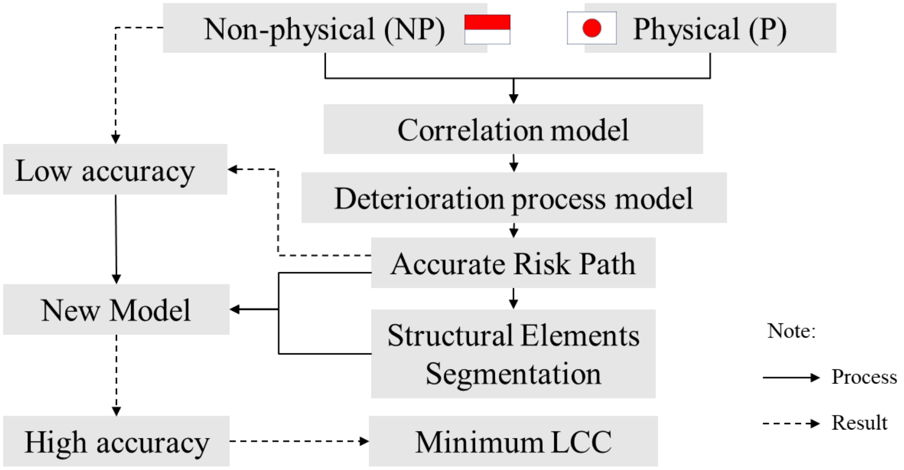


Figure 6-5. A flowchart outlining the technical implementation solutions needed to achieve the minimum life-cycle cost (LCC).

Overall, these results demonstrate that the proposed correlation-based deterioration pathway model and inspection-granularity optimization framework can be operationalized within an asset management system to deliver accurate, low-risk LCC decisions at minimum cost, providing a practical and transferable pathway for implementation in developing-country contexts.

6.2 Principal Conclusions of the Study

To address the first organizational issue, the Theory of Planned Behavior (TPB) indicates that successful bridge asset management implementation requires ensuring adequate budget availability, high-quality data, and sufficient human resources. This interpretation is consistent with expert interviews, which emphasized that reliable data and adequate resources are essential prerequisites for effective implementation. The conclusion is further reinforced by the in-depth Qualitative Comparative Analysis (QCA), which identified data as the primary factor requiring attention, alongside the need for a user-friendly management system. Taken together, these three evaluations consistently highlight data quality as the most decisive determinant in strengthening asset managers' intention to adopt bridge asset management.

To address the second issue concerning technical implementation, the proposed model represents a substantial advancement for Indonesia by improving both the accuracy of condition evaluation and the reliability of cost prediction. Although the correlation between the two assessment methods is positive, further refinement of the evaluation criteria remains necessary—particularly for damage severity and damage extent—to enable more objective application and to ensure the model consistently achieves minimum LCC outcomes. Segmentation is central to this improvement, as it captures localized deterioration patterns and supports deterioration models that more closely reflect observed field conditions. With the adoption of this enhanced deterioration framework, Indonesia's bridge maintenance strategy is expected to shift toward more data-driven, targeted, and cost-efficient planning, enabling optimized interventions, more accurate budgeting, and a more sustainable national bridge asset management system.

Despite these benefits, bridge asset management implementation does not always proceed smoothly, as multiple challenges can lead to suboptimal outcomes. Effective implementation rests on three foundational requirements: (1) high-quality, validated data to minimize errors in maintenance planning and programming; (2) support from experienced personnel with appropriate qualifications and technical competence; and (3) deployment of a new system that is easier to operate and whose outputs are readily interpretable by asset managers. When these conditions are met, bridge asset management is far more likely to be implemented effectively and to deliver optimal performance.

In addition, the future guidelines proposed for bridge asset management should provide more comprehensive specifications, particularly regarding structural element segmentation and localized damage assessment. Greater procedural detail would reduce subjectivity in condition evaluation and support more effective and efficient planning, both for maintenance execution and for minimizing total life-cycle costs over the bridge's service life.

6.3 Recommendations for Future Research Directions

This study is far from perfect, and therefore, further research is needed to provide new findings and additional recommendations for the successful implementation of bridge asset management in Indonesia. Some potential areas for future research include expanding the evaluation of asset managers to include those managing infrastructure outside of national roads, such as provincial roads, urban roads, and rural roads. Additionally, the research could be extended to include different types of bridges, beyond the concrete and steel girder bridges used in this study. Increasing the sample size of bridges could also enhance the objectivity of the research findings.

Future bridge management practices in Indonesia can utilize both Non-Physical and Physical evaluation data by establishing a unified, correlated database that combines the broad historical coverage of Non-Physical assessments with the high precision of segmented Physical inspections. This integrated dataset supports more accurate deterioration modeling, optimized LCC predictions, better budget prioritization, and a scalable transition toward advanced, data-driven, and technology-supported asset management.

The issues related to asset management organization and the utilization of bridge asset management tools will continue to evolve in line with advancements in technology and the use of new materials in bridge construction. Therefore, this research will continue to yield positive outcomes, contributing to the resolution of various issues in the implementation and application of bridge asset management in the world.

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Appendix-A

A Questionnaire Survey of Asset Managers Using the Theory of Planned Behavior Framework

Introduction to the Behavioral Intention Assessment in Bridge Asset Management

My name is Risma Putra Pratama Sastrawiria, a doctoral student at Kochi University of Technology, Japan. As part of my dissertation research titled “Improvement of Bridge Asset Management: A Review of Asset Management Systems and the Implementation of a New Model in a Case Study of Indonesia’s National Road Network,” I am conducting a survey to understand the factors that influence individual bridge asset managers in carrying out and applying bridge asset management effectively.

This questionnaire is designed to map and describe the various determinants that shape the intentions and behaviors of individuals responsible for implementing bridge asset management practices in Indonesia. Completing this survey will take approximately five minutes.

I sincerely appreciate your participation. Your contribution is invaluable for advancing the future development of bridge asset management in Indonesia.

Respectfully,

Risma Putra Pratama Sastrawiria

Demographic Questions

1. Name:
2. Position / Job Title:
3. Age:
4. Email Address:
5. Gender:
    a. Male
    b. Female
6. Educational Background:
7. Work Unit / Organization:
8. Experience in Road and Bridge Asset Management
    a. 1 – 3 Years
    b. 3 – 5 Years
    c. 5 – 10 Years
    d. 10 - 15 Years
    e. 15 - 20 Years
    f. > 20 Years
9. Work Experience in the Field of Bridge Engineering (you may select more than one)
    a. Bridge Structural Analysis
    b. Bridge Visual Inspection
    c. Bridge Planning and Programming
    d. Bridge Construction
    e. Bridge Supervision
    f. Bridge Maintenance and Rehabilitation
    g. Special Inspection / Non-Destructive Testing (NDT)

10. Proof of Bridge Engineering Expertise (Certificate, Assignment Letter, or Work Experience Record)
    a. Yes
    b. No

Please indicate your level of agreement for each statement:

1 = Strongly Disagree

2 = Disagree

3 = Neutral

4 = Agree

5 = Strongly Agree

A. Attitude Toward Bridge Asset Management

Please indicate your level of agreement with the following statements:

No.	Statement	1 2 3 4 5
1	I am willing to allocate the necessary budget for implementing a bridge asset management system, as budget availability influences my attitude toward its implementation.	○ ○ ○ ○ ○
2	I am willing to improve data quality to support better implementation of bridge asset management, as high-quality data influences my attitude toward conducting asset management effectively.	○ ○ ○ ○ ○
3	I am willing to update policies to support better implementation of bridge asset management, as appropriate policies influence my attitude toward carrying out asset management.	○ ○ ○ ○ ○
4	I am willing to allocate staff and equipment for bridge asset management implementation, as resource availability influences my attitude toward performing asset management.	○ ○ ○ ○ ○
5	I am willing to enhance existing systems to improve bridge asset management, as system capability influences my attitude toward performing asset management.	○ ○ ○ ○ ○

B. Subjective Norms

No.	Statement	1 2 3 4 5
6	I prefer allocating adequate budgets for bridge asset management, as budget availability influences my work environment and behavior.	○ ○ ○ ○ ○

No.	**Statement**	**1 2 3 4 5**
7	I prefer improving data quality for use in bridge asset management, as high-quality data influences my work environment and behavior.	○ ○ ○ ○ ○
8	I prefer updating policies to enhance bridge asset management, as appropriate policies influence my work environment and behavior.	○ ○ ○ ○ ○
9	I prefer allocating staff and equipment to support bridge asset management implementation, as resource availability influences my work environment and behavior.	○ ○ ○ ○ ○
10	I prefer upgrading existing systems to support better bridge asset management, as system suitability influences my work environment and behavior.	○ ○ ○ ○ ○

C. Perceived Behavioral Control

No.	**Statement**	**1 2 3 4 5**
11	I believe that allocating a sufficient budget will improve the quality of bridge planning and programming.	○ ○ ○ ○ ○
12	I believe that accurate and reliable data directly enhances the effectiveness of bridge asset management.	○ ○ ○ ○ ○
13	I believe that an appropriate policy framework will improve the implementation of bridge asset management.	○ ○ ○ ○ ○
14	I believe that clearly defining staff roles and ensuring the availability of inspection tools will improve bridge asset management implementation.	○ ○ ○ ○ ○
15	I believe that a system that meets operational needs is essential for accurate and effective bridge asset management.	○ ○ ○ ○ ○

D. Behavioral Attitude Toward Adoption

No.	**Statement**	**1 2 3 4 5**
16	I am willing to implement bridge asset management to improve the durability and service life of bridges.	○ ○ ○ ○ ○
17	I will implement bridge asset management because it improves cost-effectiveness and efficiency in bridge maintenance.	○ ○ ○ ○ ○

E. Influence of Subjective Norms

No.	Statement	1 2 3 4 5
18	I prefer supporting bridge asset management as recommended by my colleagues.	○ ○ ○ ○ ○
19	I prefer participating in bridge asset management as recommended by my supervisors.	○ ○ ○ ○ ○
20	I prefer supporting bridge asset management as directed by my organization.	○ ○ ○ ○ ○

F. Perceived Behavioral Control Toward Implementation

No.	Statement	1 2 3 4 5
21	I believe that allocating sufficient time and resources will improve bridge asset management outcomes.	○ ○ ○ ○ ○
22	I believe that proactive actions are necessary to support effective bridge asset management implementation.	○ ○ ○ ○ ○
23	I am confident in the success of bridge asset management and will recommend it to my colleagues.	○ ○ ○ ○ ○

G. Behavioral Intention

No.	Statement	1 2 3 4 5
24	I intend to implement bridge asset management.	○ ○ ○ ○ ○
25	I intend to recommend bridge asset management to my colleagues, supervisors, and organization.	○ ○ ○ ○ ○
26	I plan to allocate time and resources to ensure effective bridge asset management implementation.	○ ○ ○ ○ ○
27	I am willing to be proactive and contribute to the implementation of bridge asset management.	○ ○ ○ ○ ○

Appendix-B

Questionnaire Survey of Concrete and Steel Girder Evaluation

Evaluation of Bridge Element Condition Assessment for Concrete Girder and Steel Girder Types

Respectfully,

I am Risma Putra Pratama Sastrawiria, a doctoral student at Kochi University of Technology, Japan. In the context of dissertation study activities "Improvement of Bridge Asset Management: A Review of Asset Management System and Implementation of New Model on a Case Study in Indonesia National Road", I would like to ask some questions regarding the visual bridge condition assessment using this evaluation form.

This evaluation form is addressed to field inspectors who carry out detailed visual bridge inspections. This evaluation activity is carried out to see the amount of gap / difference in perception between each inspector on the visual condition of the bridge which will be presented in the form of photos. The results of this evaluation will be used as research data which is expected to be useful in the future for the development of bridge asset management in Indonesia.

In closing, the author would like to thank you for your participation in filling out this questionnaire, hopefully it can be useful for the future progress of bridge asset management in Indonesia.

Best regards,

Risma Putra Pratama Sastrawiria

Demographic Questions

1. Gender:

a. Male

b. Female

2. Age:

a. < 25 Year

b. 25 - 30 Year

c. 30 - 35 Year

d. 35 - 40 Year

e. 40 Year >

3. Experience as a bridge inspector:

a. < 1 Year

b. 1 - 3 Year

c. - 5 Year

d. 5 - 10 Year

e. > 10 Year

4. Do you have a certificate/expertise as a bridge inspector?

a. Yes

b. No

Assessment Questions
Choose the condition value that you think best matches the visual conditions in the picture. The assessment is assumed to occur on a specific part/segment of the bridge element, so the damage assessment is localised, not an overall condition assessment for the entire bridge.

(The images included in the original questionnaire were provided in higher resolution)

1. What is the condition value for crack damage in this concrete girder?

(a, b, c, d, e) or (0,1,2,3,4,5)

2. What is the condition value for the porousness of this concrete girder?

(a, b, c, d, e) or (0,1,2,3,4,5)

3. What is the condition value for concrete reinforcement corrosion on this girder?

(a, b, c, d, e) or (0,1,2,3,4,5)

4. What is the condition value for concrete reinforcement corrosion on this girder?

(a, b, c, d, e) or (0,1,2,3,4,5)

5. What is the condition value for concrete reinforcement corrosion on this girder?

(a, b, c, d, e) or (0,1,2,3,4,5)

6. What is the condition value for concrete reinforcement corrosion on this girder?

(a, b, c, d, e) or (0,1,2,3,4,5)

7. What is the condition value for concrete reinforcement corrosion on this girder?

(a, b, c, d, e) or (0,1,2,3,4,5)

8. What is the condition value for concrete reinforcement corrosion on this girder?

(a, b, c, d, e) or (0,1,2,3,4,5)

9. What is the condition value for concrete reinforcement corrosion on this girder?

(a, b, c, d, e) or (0,1,2,3,4,5)

10. What is the condition value for concrete reinforcement corrosion on this girder?

(a, b, c, d, e) or (0,1,2,3,4,5)

11. What is the condition value for crack damage on this girder?

(a, b, c, d, e) or (0,1,2,3,4,5)

12. What is the condition value for concrete spalling damage on this girder?

(a, b, c, d, e) or (0,1,2,3,4,5)

13. What is the condition value for corrosion damage on this section of steel girder?

(a, b, c, d, e) or (0,1,2,3,4,5)

14. What is the condition value for corrosion damage on this steel girder section?

(a, b, c, d, e) or (0,1,2,3,4,5)

15. What is the condition value for corrosion damage on this steel girder support section?

(a, b, c, d, e) or (0,1,2,3,4,5)

16. What is the condition value for the paint surface damage on this steel girder?

(a, b, c, d, e) or (0,1,2,3,4,5)

17. What is the condition value for the paint surface damage on this steel girder?

(a, b, c, d, e) or (0,1,2,3,4,5)

18. What is the condition value for the paint surface damage on this steel girder?

(a, b, c, d, e) or (0,1,2,3,4,5)

19. What is the condition value for corrosion damage at this steel girder joint section?

(a, b, c, d, e) or (0,1,2,3,4,5)

20. What is the condition value for corrosion damage on this steel girder?

(a, b, c, d, e) or (0,1,2,3,4,5)

21. What is the condition value for paint damage on this steel girder?

(a, b, c, d, e) or (0,1,2,3,4,5)

22. What is the condition value for corrosion damage on this steel girder?

(a, b, c, d, e) or (0,1,2,3,4,5)

23. What is the condition value for corrosion damage on this steel girder?

(a, b, c, d, e) or (0,1,2,3,4,5)

24. What is the condition value for corrosion damage on this steel girder?

(a, b, c, d, e) or (0,1,2,3,4,5)

25. What is the condition value for rust damage on this steel girder?

(a, b, c, d, e) or (0,1,2,3,4,5)

26. What is the condition value for corrosion damage on this steel girder?

(a, b, c, d, e) or (0,1,2,3,4,5)

27. What is the condition value for corrosion damage on this steel girder?

(a, b, c, d, e) or (0,1,2,3,4,5)

28. What is the condition value for paint surface deterioration on this steel girder?

(a, b, c, d, e) or (0,1,2,3,4,5)

29. What is the condition value for the deterioration of the paint surface on this steel girder?

(a, b, c, d, e) or (0,1,2,3,4,5)

30. What is the condition value for the deterioration of the paint surface on this steel girder?

(a, b, c, d, e) or (0,1,2,3,4,5)

31. What is the condition value for paint surface deterioration on this steel girder?

(a, b, c, d, e) or (0,1,2,3,4,5)

Appendix-C

Expert Assessment of Bridge Visual Condition Sample Data

Concrete Girder Bridge Damage Sample

Damage Sample	Type of Damage	S	R	K	F	P	NP	P
1	Delamination	1	1	0	0	0	2	e
2	Delamination	1	1	1	0	0	3	e
3	Spalling	1	1	0	0	0	2	c
4	Delamination	1	1	1	0	0	3	e
5	Exposed Rebars	1	1	1	0	0	3	d
6	Exposed Rebars	1	1	1	0	0	3	d
7	Delamination	1	1	1	0	0	3	e
8	Exposed Rebars	1	1	0	0	0	2	d
9	Delamination	1	1	0	0	0	2	e
10	Spalling	1	1	0	0	0	2	d
11	Spalling	1	1	0	0	0	2	d
12	Delamination	1	1	1	0	0	3	e
13	Exposed Rebars	1	1	1	0	0	3	d
14	Exposed Rebars	1	1	1	0	0	3	d
15	Delamination	1	1	0	0	0	2	e
16	Exposed Rebars	1	1	1	0	0	3	d
17	Exposed Rebars	1	1	1	0	0	3	e
18	Exposed Rebars	1	1	1	0	0	3	e
19	Exposed Rebars	1	1	1	0	0	3	e
20	Delamination	1	1	0	0	0	2	e
21	Exposed Rebars	1	1	1	0	0	3	d
22	Exposed Rebars	1	1	1	0	0	3	e
23	Exposed Rebars	1	1	1	0	0	3	e
24	Exposed Rebars	1	1	1	0	0	3	e
25	Exposed Rebars	1	1	1	0	0	3	e
26	Exposed Rebars	1	1	1	0	0	3	e
27	Exposed Rebars	1	1	1	0	0	3	e
28	Exposed Rebars	1	1	1	0	0	3	e
29	Exposed Rebars	1	1	1	0	0	3	e
30	Cracking and Leaking	1	1	1	0	0	3	c
31	Delamination	1	1	0	0	0	2	e
32	Exposed Rebars	1	1	1	0	0	3	d
33	Exposed Rebars	1	1	1	0	0	3	d
34	Exposed Rebars	1	1	1	0	0	3	d
35	Cracking and Leaking	1	1	1	0	0	3	d
36	Delamination	1	1	0	0	0	2	e
37	Exposed Rebars	1	1	1	0	0	3	e
38	Exposed Rebars	1	1	1	0	0	3	e
39	Delamination	1	1	0	0	0	2	e
40	Delamination	1	1	0	0	0	2	e
41	Exposed Rebars	1	1	1	0	0	3	e
42	Exposed Rebars	1	1	1	0	0	3	e
43	Exposed Rebars	1	1	1	0	0	3	e

Damage Sample	Type of Damage	S	R	K	F	P	NP	P
44	Cracking and Leaking	1	1	1	0	0	3	e
45	Cracking and Leaking	1	1	1	0	0	3	e
46	Cracking and Leaking	1	1	1	0	0	3	e
47	Exposed Rebars	1	1	0	0	0	2	d
48	Exposed Rebars	1	1	0	0	0	2	d
49	Exposed Rebars	1	1	0	0	0	2	d
50	Delamination	1	1	1	0	0	3	e
51	Exposed Rebars	1	1	1	0	0	3	d
52	Exposed Rebars	1	1	1	0	0	3	d
53	Exposed Rebars	1	1	1	0	0	3	d
54	Exposed Rebars	1	1	1	0	0	3	d
55	Delamination	1	1	1	0	0	3	e
56	Cracking	1	0	1	0	0	2	b
57	Cracking	1	0	1	0	0	2	b
58	Cracking	1	0	1	0	0	2	b
59	Cracking and Leaking	1	1	1	0	0	3	d
60	Cracking and Leaking	1	1	1	0	0	3	d
61	Cracking and Leaking	1	1	1	0	0	3	d
62	Cracking and Leaking	1	1	1	0	0	3	d
63	Delamination	1	1	1	0	0	3	e
64	Exposed Rebars	1	1	0	0	0	2	d
65	Delamination	1	1	0	0	0	2	e
66	Exposed Rebars	1	1	1	0	0	3	e
67	Exposed Rebars	1	1	1	0	0	3	e
68	Exposed Rebars	1	1	1	0	0	3	e
69	Exposed Rebars	1	1	1	0	0	3	e
70	Exposed Rebars	1	1	1	0	0	3	d
71	Exposed Rebars	1	1	1	0	0	3	d
72	Exposed Rebars	1	1	1	0	0	3	d
73	Delamination	1	1	1	0	0	3	e
74	Exposed Rebars	1	1	0	0	0	2	d
75	Delamination	1	1	0	0	0	2	d
76	Exposed Rebars	1	1	1	0	0	3	d
77	Delamination	1	1	0	0	0	2	e
78	Exposed Rebars	1	1	1	0	0	3	d
79	Exposed Rebars	1	1	1	0	0	3	d
80	Exposed Rebars	1	1	1	0	0	3	d
81	Delamination	1	1	0	0	0	2	d
82	Delamination	1	1	0	0	0	2	d
83	Cracking	1	0	1	0	0	2	d
84	Cracking	1	0	1	0	0	2	d
85	Exposed Rebars	1	1	0	0	0	2	d
86	Exposed Rebars	1	1	0	0	0	2	d
87	Exposed Rebars	1	1	0	0	0	2	d
88	Exposed Rebars	1	1	0	0	0	2	d

Damage Sample	Type of Damage	S	R	K	F	P	NP	P
89	Exposed Rebars	1	1	0	0	0	2	d
90	Exposed Rebars	1	1	0	0	0	2	d
91	Cracking	1	0	1	0	0	2	c
92	Cracking	1	0	1	0	0	2	c
93	Delamination	1	1	0	0	0	2	c
94	Delamination	1	1	0	0	0	2	c
95	Delamination	1	1	0	0	0	2	c
96	Delamination	1	1	0	0	0	2	c
97	Cracking	1	0	0	0	0	1	b
98	Cracking	1	0	0	0	0	1	b
99	Cracking	1	0	1	0	0	2	d
100	Cracking	1	0	1	0	0	2	d
101	Cracking	1	0	1	0	0	2	d
102	Cracking	1	0	1	0	0	2	d
103	Exposed Rebars	1	1	0	0	0	2	d
104	Spalling	1	0	0	0	0	1	c
105	Spalling	1	0	0	0	0	1	c
106	Spalling	1	0	0	0	0	1	c
107	Exposed Rebars	1	1	0	0	0	2	d
108	Exposed Rebars	1	1	0	0	0	2	d
109	Spalling	1	0	0	0	0	1	c
110	Spalling	1	0	0	0	0	1	c
111	Spalling	1	0	0	0	0	1	c
112	Spalling	1	0	0	0	0	1	c
113	Delamination	1	0	0	0	0	1	c
114	Delamination	1	0	0	0	0	1	c
115	Spalling	1	0	0	0	0	1	c
116	Spalling	1	0	0	0	0	1	c
117	Spalling	1	0	0	0	0	1	c
118	Delamination	1	0	0	0	0	1	c
119	Exposed Rebars	1	1	0	0	0	2	d
120	Cracking	1	0	1	0	0	2	c
121	Cracking	1	0	1	0	0	2	d
122	Delamination	1	1	1	0	0	3	e
123	Delamination	1	1	0	0	0	2	c
124	Exposed Rebars	1	1	0	0	0	2	d
125	Exposed Rebars	1	1	0	0	0	2	d
126	Exposed Rebars	1	1	0	0	0	2	d
127	Cracking	1	0	1	0	0	2	d
128	Delamination	1	1	0	0	0	2	c
129	Delamination	1	1	0	0	0	2	d
130	Spalling	1	1	0	0	0	2	d
131	Delamination	1	1	0	0	0	2	d
132	Delamination	1	1	0	0	0	2	d
133	Delamination	1	1	0	0	0	2	d

Damage Sample	Type of Damage	S	R	K	F	P	NP	P
134	Delamination	1	1	0	0	0	2	d
135	Delamination	1	1	1	0	0	3	d
136	Exposed Rebars	1	1	1	0	0	3	e
137	Exposed Rebars	1	1	1	0	0	3	e
138	Delamination	1	1	0	0	0	2	e
139	Exposed Rebars	1	1	1	0	0	3	e
140	Exposed Rebars	1	1	1	0	0	3	e
141	Spalling	1	1	0	0	0	2	d
142	Spalling	1	1	0	0	0	2	d
143	Spalling	1	1	0	0	0	2	c
144	Cracking	1	0	1	0	0	2	c
145	Cracking	1	0	1	0	0	2	c
146	Delamination	1	1	1	0	0	3	e
147	Exposed Rebars	1	1	1	0	0	3	d
148	Exposed Rebars	1	1	1	0	0	3	d
149	Cracking	1	0	1	0	0	2	c
150	Cracking	1	0	1	0	0	2	b
151	Exposed Rebars	1	1	0	0	0	2	d
152	Exposed Rebars	1	1	0	0	0	2	d
153	Cracking and Leaking	1	1	1	0	0	3	e
154	Cracking and Leaking	1	1	1	0	0	3	e
155	Delamination	1	1	0	0	0	2	c
156	Exposed Rebars	1	1	1	0	0	3	d
157	Spalling	1	1	0	0	0	2	c
158	Delamination	1	1	0	0	0	2	e
159	Exposed Rebars	1	1	0	0	0	2	d
160	Exposed Rebars	1	1	0	0	0	2	d
161	Exposed Rebars	1	1	0	0	0	2	d
162	Exposed Rebars	1	1	0	0	0	2	d
163	Delamination	1	1	0	0	0	2	e
164	Exposed Rebars	1	1	0	0	0	2	d
165	Cracking	1	1	1	0	0	3	d
166	Cracking	1	1	1	0	0	3	d
167	Cracking	1	1	1	0	0	3	d
168	Cracking	1	1	1	0	0	3	d
169	Delamination	1	1	0	0	0	2	c
170	Cracking	1	1	1	0	0	3	d
171	Cracking	1	1	1	0	0	3	d
172	Cracking	1	1	1	0	0	3	d
173	Cracking	1	1	1	0	0	3	e
174	Cracking	1	1	1	0	0	3	e
175	Cracking	1	1	1	0	0	3	e
176	Cracking	1	1	1	0	0	3	e
177	Delamination	1	1	0	0	0	2	d
178	Delamination	1	1	0	0	0	2	d

Damage Sample	Type of Damage	S	R	K	F	P	NP	P
179	Delamination	1	1	0	0	0	2	c
180	Delamination	1	1	0	0	0	2	c
181	Delamination	1	1	0	0	0	2	c
182	Delamination	1	1	0	0	0	2	c
183	Cracking	1	1	1	0	0	3	e
184	Cracking	1	1	1	0	0	3	e
185	Cracking	1	0	1	0	0	2	c
186	Delamination	1	1	1	0	0	3	e
187	Cracking	1	1	1	0	0	3	c
188	Delamination	1	1	0	0	0	2	c
189	Cracking and Leaking	1	1	1	0	0	3	e
190	Cracking and Leaking	1	1	1	0	0	3	e
191	Cracking and Leaking	1	1	1	0	0	3	e
192	Exposed Rebars	1	1	0	0	0	2	e
193	Cracking	1	0	1	0	0	2	c
194	Cracking	1	0	1	0	0	2	c
195	Cracking	1	1	1	0	0	3	e
196	Cracking	1	1	1	0	0	3	e
197	Cracking	1	0	1	0	0	2	c
198	Cracking	1	0	1	0	0	2	c
199	Cracking	1	0	1	0	0	2	c
200	Exposed Rebars	1	1	0	0	0	2	d
201	Cracking	1	1	1	0	0	3	d
202	Cracking	1	1	1	0	0	3	d
203	Cracking	1	0	1	0	0	2	c
204	Cracking	1	0	1	0	0	2	c
205	Cracking	1	0	1	0	0	2	b
206	Delamination	1	1	0	0	0	2	e
207	Cracking	1	0	1	0	0	2	b
208	Cracking	1	0	1	0	0	2	c
209	Delamination	1	1	0	0	0	2	e
210	Delamination	1	1	0	0	0	2	d
211	Exposed Rebars	1	1	0	0	0	2	d
212	Cracking	1	0	1	0	0	2	c
213	Cracking	1	1	1	0	0	3	d
214	Delamination	1	1	0	0	0	2	e
215	Exposed Rebars	1	1	0	0	0	2	d
216	Exposed Rebars	1	1	0	0	0	2	d
217	Cracking	1	0	1	0	0	2	d
218	Cracking	1	0	1	0	0	2	b
219	Exposed Rebars	1	1	1	0	0	3	d
220	Exposed Rebars	1	1	0	0	0	2	d
221	Delamination	1	1	0	0	0	2	e
222	Cracking	1	1	1	0	0	3	d
223	Cracking	1	1	1	0	0	3	d

Damage Sample	Type of Damage	S	R	K	F	P	NP	P
224	Delamination	1	1	1	0	0	3	e
225	Exposed Rebars	1	1	1	0	0	3	d
226	Cracking	1	0	1	0	0	2	d
227	Cracking	1	1	1	0	0	3	d
228	Spalling	1	0	0	0	0	1	c
229	Exposed Rebars	1	1	0	0	0	2	d
230	Delamination	1	1	0	0	0	2	d
231	Cracking	1	0	0	0	0	1	c
232	Delamination	1	1	0	0	0	2	e
233	Cracking	1	0	0	0	0	1	c
234	Cracking and Leaking	1	1	1	0	0	3	d
235	Delamination	1	1	0	0	0	2	e
236	Delamination	1	1	0	0	0	2	d
237	Delamination	1	1	0	0	0	2	d
238	Exposed Rebars	1	1	1	0	0	3	d
239	Cracking	1	1	1	0	0	3	d
240	Cracking	1	1	1	0	0	3	d
241	Delamination	1	1	0	0	0	2	d
242	Cracking	1	1	1	0	0	3	d
243	Delamination	1	1	0	0	0	2	e
244	Exposed Rebars	1	1	0	0	0	2	d
245	Exposed Rebars	1	1	0	0	0	2	d
246	Cracking	1	0	1	0	0	2	c
247	Exposed Rebars	1	1	0	0	0	2	d
248	Cracking	1	0	1	0	0	2	d
249	Cracking	1	0	1	0	0	2	d
250	Cracking	1	0	1	0	0	2	d
251	Cracking	1	0	1	0	0	2	d
252	Cracking	1	0	1	0	0	2	d
253	Cracking	1	0	1	0	0	2	d
254	Exposed Rebars	1	1	0	0	0	2	d
255	Exposed Rebars	1	1	0	0	0	2	d
256	Delamination	1	1	0	0	0	2	e
257	Exposed Rebars	1	1	1	0	0	3	d
258	Exposed Rebars	1	1	1	0	0	3	d
259	Delamination	1	1	0	0	0	2	c
260	Delamination	1	1	0	0	0	2	e
261	Exposed Rebars	1	1	1	0	0	3	d
262	Exposed Rebars	1	1	0	0	0	2	d
263	Exposed Rebars	1	1	0	0	0	2	d
264	Cracking	1	0	1	0	0	2	d
265	Cracking	1	0	1	0	0	2	d
266	Exposed Rebars	1	1	0	0	0	2	d
267	Exposed Rebars	1	1	0	0	0	2	d
268	Exposed Rebars	1	1	0	0	0	2	d

Damage Sample	Type of Damage	S	R	K	F	P	NP	P
269	Delamination	1	1	0	0	0	2	e
270	Exposed Rebars	1	1	0	0	0	2	d
271	Exposed Rebars	1	1	0	0	0	2	d
272	Spalling	1	1	0	0	0	2	d
273	Spalling	1	0	0	0	0	1	c
274	Delamination	1	1	0	0	0	2	e
275	Spalling	1	0	0	0	0	1	c
276	Exposed Rebars	1	1	0	0	0	2	d
277	Delamination	1	0	0	0	0	1	d
278	Cracking	1	0	1	0	0	2	d
279	Cracking	1	0	1	0	0	2	d
280	Delamination	1	1	0	0	0	2	d
281	Exposed Rebars	1	1	0	0	0	2	d
282	Delamination	1	1	0	0	0	2	c
283	Delamination	1	1	0	0	0	2	c
284	Delamination	1	0	0	0	0	1	c
285	Delamination	1	0	0	0	0	1	c
286	Spalling	1	0	0	0	0	1	c
287	Spalling	1	0	0	0	0	1	c
288	Delamination	1	1	0	0	0	2	d
289	Delamination	1	0	0	0	0	1	c
290	Spalling	1	0	0	0	0	1	e
291	Spalling	1	0	0	0	0	1	e
292	Cracking	1	0	1	0	0	2	d
293	Cracking	1	0	1	0	0	2	d
294	Cracking	1	0	1	0	0	2	d
295	Cracking	1	0	1	0	0	2	e
296	Cracking	1	0	1	0	0	2	c
297	Cracking	1	0	1	0	0	2	d
298	Cracking	1	0	1	0	0	2	d
299	Cracking	1	0	1	0	0	2	c
300	Cracking	1	0	1	0	0	2	d
301	Cracking	1	0	1	0	0	2	d
302	Cracking	1	0	1	0	0	2	d
303	Cracking	1	0	1	0	0	2	d
304	Cracking	1	0	1	0	0	2	d
305	Delamination	1	1	0	0	0	2	e
306	Delamination	1	1	0	0	0	2	e
307	Cracking	1	0	1	0	0	2	d
308	Cracking	1	0	1	0	0	2	c
309	Cracking	1	0	1	0	0	2	c
310	Cracking	1	0	1	0	0	2	d
311	Cracking	1	0	1	0	0	2	c
312	Cracking	1	0	1	0	0	2	c
313	Cracking	1	0	1	0	0	2	d

Damage Sample	Type of Damage	S	R	K	F	P	NP	P
314	Cracking	1	0	1	0	0	2	d
315	Cracking	1	0	1	0	0	2	d
316	Cracking	1	0	1	0	0	2	d
317	Cracking	1	0	1	0	0	2	d
318	Cracking	1	0	1	0	0	2	d
319	Cracking	1	0	1	0	0	2	d
320	Delamination	1	1	0	0	0	2	e
321	Delamination	1	1	0	0	0	2	e
322	Delamination	1	1	0	0	0	2	e
323	Cracking	1	0	1	0	0	2	d
324	Cracking	1	0	1	0	0	2	d
325	Cracking	1	0	1	0	0	2	d
326	Cracking	1	0	1	0	0	2	d
327	Cracking	1	0	1	0	0	2	d
328	Cracking	1	0	1	0	0	2	d
329	Cracking	1	0	1	0	0	2	d
330	Exposed Rebars	1	1	0	0	0	2	e
331	Cracking	1	0	1	0	0	2	d
332	Cracking	1	0	1	0	0	2	d
333	Cracking	1	0	1	0	0	2	d
334	Cracking	1	0	1	0	0	2	d
335	Cracking	1	0	1	0	0	2	d
336	Delamination	1	1	0	0	0	2	e
337	Delamination	1	1	0	0	0	2	e
338	Cracking	1	0	1	0	0	2	d
339	Cracking	1	0	1	0	0	2	d
340	Cracking	1	0	1	0	0	2	d
341	Spalling	1	0	0	0	0	1	c
342	Delamination	1	1	0	0	0	2	e
343	Delamination	1	1	0	0	0	2	e
344	Cracking	1	0	1	0	0	2	d
345	Delamination	1	0	0	0	0	1	d
346	Cracking	1	0	1	0	0	2	d
347	Cracking	1	0	1	0	0	2	d
348	Cracking	1	0	1	0	0	2	d
349	Cracking	1	0	1	0	0	2	d
350	Delamination	1	1	0	0	0	2	d
351	Delamination	1	1	0	0	0	2	e
352	Cracking	1	0	1	0	0	2	d
353	Delamination	1	1	0	0	0	2	e
354	Cracking	1	1	1	0	0	3	e
355	Cracking	1	1	1	0	0	3	d
356	Delamination	1	1	0	0	0	2	d
357	Cracking	1	0	1	0	0	2	d
358	Cracking	1	1	1	0	0	3	e

Damage Sample	Type of Damage	S	R	K	F	P	NP	P
359	Cracking	1	1	1	0	0	3	e
360	Delamination	1	1	0	0	0	2	e
361	Cracking	1	1	1	0	0	3	d
362	Cracking	1	1	1	0	0	3	e
363	Cracking	1	1	1	0	0	3	e
364	Cracking	1	1	1	0	0	3	d
365	Cracking	1	1	1	0	0	3	d
366	Exposed Rebars	1	1	0	0	0	2	d
367	Cracking	1	1	1	0	0	3	d
368	Cracking	1	1	1	0	0	3	e
369	Delamination	1	1	0	0	0	2	c
370	Cracking	1	0	1	0	0	2	d
371	Cracking	1	0	1	0	0	2	d
372	Cracking	1	0	1	0	0	2	c
373	Cracking	1	1	1	0	0	3	d
374	Delamination	1	1	0	0	0	2	c
375	Delamination	1	1	0	0	0	2	c
376	Cracking	1	0	1	0	0	2	d
377	Delamination	1	1	0	0	0	2	c
378	Cracking	1	0	1	0	0	2	d
379	Delamination	1	1	0	0	0	2	c
380	Cracking	1	1	1	0	0	3	d
381	Cracking	1	1	1	0	0	3	e
382	Delamination	1	1	0	0	0	2	c
383	Cracking	1	1	1	0	0	3	d
384	Cracking	1	1	1	0	0	3	e
385	Cracking	1	1	1	0	0	3	e
386	Cracking	1	1	1	0	0	3	e
387	Cracking	1	1	1	0	0	3	d
388	Cracking	1	1	1	0	0	3	d
389	Cracking	1	1	1	0	0	3	d
390	Cracking	1	1	1	0	0	3	d
391	Cracking	1	1	1	0	0	3	d
392	Cracking	1	1	1	0	0	3	d
393	Cracking	1	1	1	0	0	3	e
394	Delamination	0	0	0	0	0	0	a
395	Delamination	0	0	0	0	0	0	a
396	Cracking	1	0	1	0	0	2	d
397	Delamination	0	0	0	0	0	0	a
398	Delamination	1	1	0	0	0	2	e
399	Delamination	0	0	0	0	0	0	a
400	Delamination	0	0	0	0	0	0	a
401	Exposed Rebars	1	1	0	0	0	2	d
402	Exposed Rebars	1	1	0	0	0	2	d
403	Cracking	1	0	1	0	0	2	d

Damage Sample	Type of Damage	S	R	K	F	P	NP	P
404	Exposed Rebars	1	1	0	0	0	2	d
405	Exposed Rebars	1	1	0	0	0	2	d
406	Exposed Rebars	1	1	0	0	0	2	d
407	Exposed Rebars	1	1	0	0	0	2	d
408	Exposed Rebars	1	1	0	0	0	2	d
409	Exposed Rebars	1	1	0	0	0	2	d
410	Cracking	1	0	1	0	0	2	d
411	Spalling	1	0	0	0	0	1	c
412	Spalling	1	0	0	0	0	1	c
413	Delamination	1	1	0	0	0	2	e
414	Delamination	1	1	0	0	0	2	e
415	Delamination	1	1	0	0	0	2	e
416	Exposed Rebars	1	1	0	0	0	2	e
417	Delamination	1	1	0	0	0	2	e
418	Exposed Rebars	1	1	0	0	0	2	e
419	Delamination	1	1	0	0	0	2	d
420	Delamination	1	1	0	0	0	2	d
421	Exposed Rebars	1	1	0	0	0	2	d
422	Exposed Rebars	1	1	0	0	0	2	d
423	Exposed Rebars	1	1	0	0	0	2	d
424	Spalling	1	0	0	0	0	1	c
425	Exposed Rebars	1	1	0	0	0	2	d
426	Exposed Rebars	1	1	0	0	0	2	d
427	Exposed Rebars	1	1	0	0	0	2	d
428	Spalling	1	0	0	0	0	1	c
429	Cracking	1	0	1	0	0	2	d
430	Exposed Rebars	1	1	0	0	0	2	d
431	Exposed Rebars	0	0	0	0	0	0	a
432	Exposed Rebars	0	0	0	0	0	0	a
433	Delamination	1	0	0	0	0	1	c
434	Exposed Rebars	1	1	0	0	0	2	c
435	Spalling	1	0	0	0	0	1	c
436	Exposed Rebars	1	1	0	0	0	2	d
437	Exposed Rebars	1	1	0	0	0	2	d
438	Exposed Rebars	1	1	0	0	0	2	d
439	Cracking	1	0	1	0	0	2	d
440	Exposed Rebars	1	1	0	0	0	2	d
441	Exposed Rebars	1	1	0	0	0	2	d
442	Exposed Rebars	1	1	0	0	0	2	d
443	Delamination	1	0	0	0	0	1	c
444	Exposed Rebars	1	1	0	0	0	2	d
445	Delamination	1	1	0	0	0	2	d
446	Exposed Rebars	1	1	0	0	0	2	d
447	Exposed Rebars	1	1	0	0	0	2	d
448	Delamination	1	1	0	0	0	2	d

Damage Sample	Type of Damage	S	R	K	F	P	NP	P
449	Spalling	1	0	0	0	0	1	c
450	Exposed Rebars	1	1	0	0	0	2	d
451	Spalling	1	0	0	0	0	1	c
452	Spalling	1	0	0	0	0	1	c
453	Cracking	1	0	1	0	0	2	d
454	Cracking	1	0	1	0	0	2	d
455	Delamination	1	1	1	0	0	3	e
456	Delamination	1	1	0	0	0	2	d
457	Delamination	1	1	0	0	0	2	d
458	Delamination	1	0	0	0	0	1	c
459	Cracking	1	0	1	0	0	2	d
460	Cracking	1	0	1	0	0	2	d
461	Cracking	1	0	0	0	0	1	b
462	Exposed Rebars	1	1	0	0	0	2	d
463	Cracking	1	0	0	0	0	1	b
464	Spalling	1	0	0	0	0	1	c
465	Spalling	1	0	0	0	0	1	c
466	Spalling	1	0	0	0	0	1	c
467	Spalling	1	0	0	0	0	1	c
468	Delamination	1	0	0	0	0	1	c
469	Delamination	1	0	0	0	0	1	c
470	Delamination	1	0	0	0	0	1	c
471	Delamination	1	0	0	0	0	1	c
472	Exposed Rebars	1	1	1	0	0	3	e
473	Exposed Rebars	1	1	0	0	0	2	e
474	Exposed Rebars	1	1	0	0	0	2	e
475	Exposed Rebars	1	1	0	0	0	2	e
476	Delamination	0	0	0	0	0	0	a
477	Delamination	0	0	0	0	0	0	a
478	Delamination	0	0	0	0	0	0	a
479	Delamination	0	0	0	0	0	0	a
480	Delamination	0	0	0	0	0	0	a
481	Delamination	0	0	0	0	0	0	a
482	Delamination	0	0	0	0	0	0	a
483	Delamination	0	0	0	0	0	0	a
484	Delamination	0	0	0	0	0	0	a
485	Delamination	0	0	0	0	0	0	a
486	Delamination	0	0	0	0	0	0	a
487	Delamination	0	0	0	0	0	0	a
488	Delamination	0	0	0	0	0	0	a
489	Delamination	1	0	0	0	0	1	c
490	Delamination	0	0	0	0	0	0	a
491	Delamination	0	0	0	0	0	0	a
492	Delamination	0	0	0	0	0	0	a
493	Delamination	0	0	0	0	0	0	a

Damage Sample	Type of Damage	S	R	K	F	P	NP	P
494	Delamination	0	0	0	0	0	0	a
495	Delamination	0	0	0	0	0	0	a
496	Delamination	0	0	0	0	0	0	a
497	Delamination	0	0	0	0	0	0	a
498	Delamination	0	0	0	0	0	0	a
499	Delamination	0	0	0	0	0	0	a
500	Delamination	0	0	0	0	0	0	a
501	Delamination	0	0	0	0	0	0	a
502	Delamination	0	0	0	0	0	0	a
503	Cracking	0	0	0	0	0	0	a
504	Cracking	0	0	0	0	0	0	a
505	Cracking	1	0	0	0	0	1	c
506	Cracking	1	0	0	0	0	1	c
507	Cracking	1	0	0	0	0	1	c
508	Cracking	1	0	0	0	0	1	c
509	Delamination	0	0	0	0	0	0	a
510	Delamination	0	0	0	0	0	0	a
511	Cracking	1	0	0	0	0	1	b
512	Cracking	1	0	0	0	0	1	b
513	Delamination	0	0	0	0	0	0	a
514	Cracking	1	0	0	0	0	1	a
515	Cracking	1	0	0	0	0	1	a
516	Delamination	0	0	0	0	0	0	a
517	Cracking	1	0	0	0	0	1	a
518	Cracking	1	0	0	0	0	1	a
519	Cracking	1	0	0	0	0	1	a
520	Cracking	1	0	0	0	0	1	a
521	Cracking	1	0	0	0	0	1	c
522	Cracking	1	0	0	0	0	1	c
523	Delamination	1	0	0	0	0	1	c
524	Delamination	1	0	0	0	0	1	c
525	Delamination	0	0	0	0	0	0	a
526	Cracking	0	0	0	0	0	0	a
527	Cracking	1	1	1	0	0	3	d
528	Cracking	1	1	1	0	0	3	d
529	Cracking	1	0	1	0	0	2	d
530	Cracking	1	0	1	0	0	2	d
531	Cracking	1	0	1	0	0	2	d
532	Cracking	1	1	1	0	0	3	d
533	Cracking	1	1	1	0	0	3	d
534	Cracking	1	1	1	0	0	3	d
535	Cracking	1	1	1	0	0	3	d
536	Cracking	1	1	1	0	0	3	d
537	Cracking	1	1	1	0	0	3	d
538	Cracking	1	0	1	0	0	2	d

Damage Sample	Type of Damage	S	R	K	F	P	NP	P
539	Cracking	1	1	1	0	0	3	d
540	Cracking	1	1	1	0	0	3	d
541	Cracking	1	1	1	0	0	3	d
542	Cracking	1	1	1	0	0	3	d
543	Cracking	1	1	1	0	0	3	d
544	Cracking	1	1	1	0	0	3	d
545	Cracking	1	1	1	0	0	3	d
546	Cracking	1	1	1	0	0	3	d
547	Cracking	1	0	1	0	0	2	d
548	Cracking	1	0	1	0	0	2	d
549	Cracking	1	1	1	0	0	3	d
550	Cracking	1	1	1	0	0	3	d
551	Spalling	1	0	0	0	0	1	d
552	Spalling	1	0	0	0	0	1	d
553	Spalling	1	0	0	0	0	1	d
554	Spalling	1	0	0	0	0	1	d
555	Cracking	1	0	1	0	0	2	d
556	Cracking	1	1	1	0	0	3	d
557	Delamination	1	1	0	0	0	2	e
558	Delamination	1	1	0	0	0	2	e
559	Cracking	1	1	1	0	0	3	d
560	Cracking	1	1	1	0	0	3	d
561	Cracking	1	1	1	0	0	3	d
562	Cracking	1	1	1	0	0	3	d
563	Cracking	1	1	1	0	0	3	d
564	Cracking	1	0	1	0	0	2	d
565	Cracking	1	0	1	0	0	2	d
566	Exposed Rebars	1	1	0	0	0	2	c
567	Spalling	1	0	0	0	0	1	c
568	Exposed Rebars	1	1	0	0	0	2	d
569	Exposed Rebars	1	1	0	0	0	2	d
570	Spalling	1	0	0	0	0	1	c
571	Spalling	1	0	0	0	0	1	c
572	Spalling	1	0	0	0	0	1	c
573	Spalling	1	0	0	0	0	1	c
574	Spalling	1	0	0	0	0	1	c
575	Spalling	1	0	0	0	0	1	c
576	Spalling	1	0	0	0	0	1	c
577	Spalling	1	0	0	0	0	1	c
578	Exposed Rebars	1	1	1	0	0	3	d
579	Exposed Rebars	1	1	1	0	0	3	d
580	Spalling	1	0	0	0	0	1	c
581	Spalling	1	0	0	0	0	1	c
582	Spalling	1	0	0	0	0	1	c
583	Spalling	1	0	0	0	0	1	c

Damage Sample	Type of Damage	S	R	K	F	P	NP	P
584	Cracking	1	0	1	0	0	2	d
585	Exposed Rebars	1	1	0	0	0	2	d
586	Cracking	1	0	0	0	0	1	c
587	Cracking	1	0	0	0	0	1	c
588	Cracking	1	0	0	0	0	1	c
589	Cracking	1	0	0	0	0	1	c
590	Delamination	1	1	0	0	0	2	e
591	Cracking	1	0	1	0	0	2	d
592	Cracking	1	0	1	0	0	2	d
593	Cracking	1	0	1	0	0	2	d
594	Cracking	1	0	1	0	0	2	d
595	Cracking	1	0	0	0	0	1	c
596	Delamination	1	1	0	0	0	2	e
597	Cracking	1	0	1	0	0	2	e
598	Cracking	1	0	0	0	0	1	c
599	Cracking	1	0	0	0	0	1	c
600	Exposed Rebars	1	1	0	0	0	2	d
601	Cracking	1	0	1	0	0	2	d
602	Cracking	1	0	1	0	0	2	d
603	Cracking	1	0	1	0	0	2	d
604	Cracking	1	0	1	0	0	2	d
605	Delamination	1	1	0	0	0	2	e
606	Spalling	1	0	0	0	0	1	c
607	Exposed Rebars	1	1	0	0	0	2	d
608	Spalling	1	0	0	0	0	1	c
609	Exposed Rebars	1	1	0	0	0	2	d
610	Spalling	1	0	0	0	0	1	d
611	Exposed Rebars	1	1	0	0	0	2	c
612	Spalling	1	1	0	0	0	2	e
613	Exposed Rebars	1	1	0	0	0	2	d
614	Cracking	1	0	1	0	0	2	d
615	Cracking	1	0	1	0	0	2	d
616	Exposed Rebars	1	1	0	0	0	2	d
617	Spalling	1	1	0	0	0	2	e
618	Spalling	1	0	0	0	0	1	c
619	Spalling	1	0	0	0	0	1	c
620	Cracking	1	0	1	0	0	2	d
621	Cracking	1	0	1	0	0	2	c
622	Cracking	1	0	1	0	0	2	d
623	Cracking	1	0	1	0	0	2	d
624	Cracking	1	0	1	0	0	2	d
625	Cracking	1	1	1	0	0	3	d
626	Cracking	1	1	1	0	0	3	d
627	Cracking	1	0	1	0	0	2	c
628	Cracking	1	0	1	0	0	2	c

Damage Sample	Type of Damage	S	R	K	F	P	NP	P
629	Cracking	1	0	1	0	0	2	c
630	Cracking	1	0	0	0	0	1	b
631	Delamination	1	1	0	0	0	2	e
632	Exposed Rebars	1	1	0	0	0	2	d
633	Exposed Rebars	1	1	0	0	0	2	d
634	Cracking	1	0	0	0	0	1	b
635	Cracking	1	0	0	0	0	1	b
636	Cracking	1	0	1	0	0	2	d
637	Cracking	1	0	1	0	0	2	c
638	Cracking	1	0	1	0	0	2	c
639	Cracking	1	0	1	0	0	2	c
640	Cracking	1	1	1	0	0	3	d
641	Cracking	1	1	1	0	0	3	d
642	Cracking	1	1	1	0	0	3	d
643	Cracking	1	1	1	0	0	3	d
644	Cracking	1	1	1	0	0	3	d
645	Exposed Rebars	1	1	0	0	0	2	d
646	Cracking	1	1	1	0	0	3	d
647	Cracking	1	1	1	0	0	3	d
648	Cracking	1	1	1	0	0	3	d
649	Delamination	1	1	0	0	0	2	e
650	Cracking	1	1	1	0	0	3	d
651	Cracking	1	1	1	0	0	3	d
652	Cracking	1	0	1	0	0	2	d
653	Cracking	1	1	1	0	0	3	d
654	Cracking	1	1	1	0	0	3	d
655	Cracking	1	1	1	0	0	3	d
656	Delamination	1	1	0	0	0	2	c
657	Cracking	1	1	1	0	0	3	d
658	Cracking	1	1	1	0	0	3	d
659	Cracking	1	1	1	0	0	3	d
660	Cracking	1	1	1	0	0	3	d
661	Cracking	1	1	1	0	0	3	d
662	Delamination	1	1	0	0	0	2	e
663	Exposed Rebars	1	1	0	0	0	2	e
664	Cracking	1	0	1	0	0	2	d
665	Cracking	1	1	1	0	0	3	d
666	Cracking	1	1	1	0	0	3	d
667	Exposed Rebars	1	1	0	0	0	2	d
668	Delamination	1	1	0	0	0	2	d
669	Cracking	1	0	1	0	0	2	d
670	Delamination	1	1	0	0	0	2	e
671	Cracking	1	1	1	0	0	3	d
672	Exposed Rebars	1	1	0	0	0	2	d
673	Cracking	1	1	1	0	0	3	d

Damage Sample	Type of Damage	S	R	K	F	P	NP	P
674	Spalling	1	0	0	0	0	1	c
675	Exposed Rebars	1	1	0	0	0	2	e
676	Cracking	1	0	1	0	0	2	d
677	Exposed Rebars	1	1	0	0	0	2	d
678	Delamination	1	1	0	0	0	2	e
679	Cracking	1	1	1	0	0	3	d
680	Delamination	1	1	0	0	0	2	e
681	Cracking	1	0	1	0	0	2	b
682	Exposed Rebars	1	1	0	0	0	2	d
683	Exposed Rebars	1	1	0	0	0	2	b
684	Exposed Rebars	1	1	0	0	0	2	d
685	Exposed Rebars	1	1	0	0	0	2	d
686	Exposed Rebars	1	1	0	0	0	2	d
687	Exposed Rebars	1	1	0	0	0	2	d
688	Spalling	1	0	0	0	0	1	d
689	Cracking	1	0	1	0	0	2	d
690	Exposed Rebars	1	1	0	0	0	2	d
691	Cracking	1	0	1	0	0	2	d
692	Cracking	1	0	1	0	0	2	d
693	Spalling	1	0	0	0	0	1	c
694	Cracking	1	0	1	0	0	2	c
695	Cracking	1	0	1	0	0	2	d
696	Cracking	1	0	1	0	0	2	c
697	Exposed Rebars	1	1	0	0	0	2	d
698	Exposed Rebars	1	1	0	0	0	2	d
699	Cracking	1	0	1	0	0	2	d
700	Exposed Rebars	1	1	0	0	0	2	d
701	Exposed Rebars	1	1	0	0	0	2	d
702	Exposed Rebars	1	1	0	0	0	2	d
703	Cracking	1	0	0	0	0	1	b
704	Delamination	1	0	0	0	0	1	c
705	Cracking	1	0	1	0	0	2	d
706	Cracking	1	0	1	0	0	2	d
707	Cracking	1	0	1	0	0	2	d
708	Cracking	1	0	0	0	0	1	c
709	Delamination	1	1	0	0	0	2	e
710	Spalling	1	0	0	0	0	1	c
711	Spalling	1	0	0	0	0	1	c
712	Delamination	1	1	0	0	0	2	e
713	Exposed Rebars	1	1	0	0	0	2	d
714	Exposed Rebars	1	1	0	0	0	2	d
715	Cracking	1	0	1	0	0	2	d
716	Spalling	1	0	0	0	0	1	c
717	Cracking	1	0	1	0	0	2	d
718	Exposed Rebars	1	1	0	0	0	2	d

Damage Sample	Type of Damage	S	R	K	F	P	NP	P
719	Cracking	1	0	1	0	0	2	d
720	Cracking	1	0	1	0	0	2	d
721	Cracking	1	0	0	0	0	1	b
722	Cracking	1	0	1	0	0	2	d
723	Cracking	1	0	1	0	0	2	d
724	Cracking	1	0	1	0	0	2	d
725	Cracking	1	0	1	0	0	2	d
726	Exposed Rebars	1	1	0	0	0	2	d
727	Cracking	1	0	1	0	0	2	d
728	Cracking	1	0	1	0	0	2	d
729	Exposed Rebars	1	1	0	0	0	2	d
730	Cracking	1	0	1	0	0	2	d
731	Delamination	1	1	0	0	0	2	e
732	Delamination	1	1	0	0	0	2	e
733	Spalling	1	0	0	0	0	1	c
734	Cracking	1	0	1	0	0	2	d
735	Delamination	1	1	0	0	0	2	e
736	Delamination	1	1	0	0	0	2	e
737	Cracking	1	0	1	0	0	2	d
738	Cracking	1	0	1	0	0	2	d
739	Cracking	1	0	1	0	0	2	d
740	Cracking	1	0	1	0	0	2	d
741	Cracking	1	0	1	0	0	2	d
742	Cracking	1	0	1	0	0	2	d
743	Cracking	1	0	1	0	0	2	d
744	Cracking	1	0	1	0	0	2	d
745	Cracking	1	0	1	0	0	2	d
746	Cracking	1	0	1	0	0	2	d
747	Cracking	1	0	1	0	0	2	d
748	Cracking	1	0	1	0	0	2	d
749	Delamination	1	1	0	0	0	2	e
750	Exposed Rebars	1	1	1	0	0	3	d
751	Exposed Rebars	1	1	1	0	0	3	d
752	Exposed Rebars	1	1	1	0	0	3	d
753	Delamination	1	1	0	0	0	2	e
754	Delamination	1	1	0	0	0	2	d
755	Exposed Rebars	1	1	0	0	0	2	d
756	Exposed Rebars	1	1	0	0	0	2	d
757	Exposed Rebars	1	1	0	0	0	2	d
758	Exposed Rebars	1	1	0	0	0	2	d
759	Exposed Rebars	1	1	0	0	0	2	d
760	Cracking	1	0	1	0	0	2	d
761	Cracking	1	0	1	0	0	2	d
762	Delamination	1	1	0	0	0	2	e
763	Delamination	1	1	0	0	0	2	d

Damage Sample	Type of Damage	S	R	K	F	P	NP	P
764	Delamination	1	1	0	0	0	2	d
765	Delamination	1	1	0	0	0	2	d
766	Delamination	1	1	0	0	0	2	e
767	Delamination	1	1	0	0	0	2	e
768	Exposed Rebars	1	1	1	0	0	3	e
769	Exposed Rebars	1	1	1	0	0	3	d
770	Exposed Rebars	1	1	1	0	0	3	d
771	Delamination	1	1	0	0	0	2	d
772	Cracking	1	0	1	0	0	2	c
773	Cracking	1	0	1	0	0	2	c
774	Cracking	1	0	1	0	0	2	c
775	Cracking	1	0	1	0	0	2	c
776	Cracking	1	0	1	0	0	2	b
777	Cracking	1	0	0	0	0	1	b
778	Cracking	1	0	1	0	0	2	c
779	Cracking	1	0	1	0	0	2	b
780	Cracking	1	0	1	0	0	2	b
781	Cracking	1	0	1	0	0	2	d
782	Cracking	1	0	1	0	0	2	d
783	Cracking	1	0	1	0	0	2	c
784	Cracking	1	0	1	0	0	2	c
785	Exposed Rebars	1	1	0	0	0	2	d
786	Exposed Rebars	1	1	0	0	0	2	d
787	Exposed Rebars	1	1	0	0	0	2	d
788	Cracking	1	0	1	0	0	2	d
789	Cracking	1	0	1	0	0	2	d
790	Cracking	1	0	1	0	0	2	c
791	Cracking	1	0	1	0	0	2	c
792	Cracking	1	0	1	0	0	2	c
793	Cracking	1	0	1	0	0	2	c
794	Cracking	1	0	1	0	0	2	d
795	Cracking	1	0	1	0	0	2	c
796	Cracking	1	0	1	0	0	2	d
797	Cracking	1	0	1	0	0	2	d
798	Cracking	1	0	1	0	0	2	d
799	Cracking	1	0	1	0	0	2	d
800	Cracking	1	0	1	0	0	2	d
801	Cracking	1	0	1	0	0	2	d
802	Exposed Rebars	1	1	0	0	0	2	d
803	Exposed Rebars	1	1	0	0	0	2	d
804	Exposed Rebars	1	1	0	0	0	2	d
805	Cracking	1	0	1	0	0	2	d
806	Exposed Rebars	1	1	0	0	0	2	d
807	Cracking	1	0	1	0	0	2	c
808	Spalling	1	0	0	0	0	1	c

Damage Sample	Type of Damage	S	R	K	F	P	NP	P
809	Spalling	1	0	0	0	0	1	c
810	Delamination	1	0	0	0	0	1	c
811	Delamination	0	0	0	0	0	0	a
812	Delamination	1	1	0	0	0	2	c
813	Delamination	0	0	0	0	0	0	a
814	Delamination	0	0	0	0	0	0	a
815	Cracking	1	0	1	0	0	2	d
816	Delamination	1	1	0	0	0	2	e
817	Delamination	1	1	0	0	0	2	e
818	Cracking	1	0	1	0	0	2	c
819	Cracking	1	0	1	0	0	2	c
820	Cracking	1	0	1	0	0	2	c
821	Cracking	1	0	1	0	0	2	c
822	Cracking	1	0	1	0	0	2	c
823	Delamination	1	1	0	0	0	2	e
824	Delamination	0	0	0	0	0	0	a
825	Delamination	0	0	0	0	0	0	a
826	Delamination	1	1	0	0	0	2	e
827	Cracking	1	0	1	0	0	2	d
828	Cracking	1	0	1	0	0	2	d
829	Delamination	1	1	0	0	0	2	e
830	Cracking	1	0	1	0	0	2	d
831	Cracking	1	0	1	0	0	2	e
832	cracking	0	0	0	0	0	0	a
833	Cracking	0	0	0	0	0	0	a
834	Cracking	0	0	0	0	0	0	a
835	Cracking	1	0	1	0	0	2	c
836	Delamination	1	1	0	0	0	2	d
837	Delamination	1	1	0	0	0	2	e
838	Cracking	1	0	1	0	0	2	c
839	Cracking	1	0	1	0	0	2	c
840	Cracking	1	0	1	0	0	2	c
841	Cracking	1	0	1	0	0	2	d
842	Cracking	1	0	1	0	0	2	c
843	Cracking	1	0	1	0	0	2	c
844	Cracking	1	0	1	0	0	2	c
845	Cracking	1	0	1	0	0	2	c
846	Cracking	1	0	1	0	0	2	c
847	Delamination	1	1	0	0	0	2	e
848	Cracking	1	0	1	0	0	2	c
849	Cracking	1	0	1	0	0	2	c
850	Spalling	1	0	0	0	0	1	c
851	Cracking	1	0	1	0	0	2	c
852	Exposed Rebars	1	1	0	0	0	2	d
853	Cracking	1	0	1	0	0	2	c

Damage Sample	Type of Damage	S	R	K	F	P	NP	P
854	Exposed Rebars	1	1	0	0	0	2	d
855	Cracking	1	0	1	0	0	2	c
856	Cracking	1	0	1	0	0	2	c
857	Cracking	1	0	1	0	0	2	c
858	Cracking	1	1	1	0	0	3	d
859	Cracking	1	1	1	0	0	3	d
860	Cracking	1	1	1	0	0	3	d
861	Cracking	1	1	1	0	0	3	d
862	Cracking	1	1	1	0	0	3	d
863	Cracking	1	1	1	0	0	3	d
864	Cracking	1	1	1	0	0	3	d
865	Cracking	1	1	1	0	0	3	d
866	Cracking	1	1	1	0	0	3	d
867	Cracking	1	1	1	0	0	3	d
868	Cracking	1	1	1	0	0	3	d
869	Exposed Rebars	1	1	0	0	0	2	d
870	Cracking	1	1	1	0	0	3	d
871	Cracking	1	1	1	0	0	3	d
872	Cracking	1	1	1	0	0	3	d
873	Cracking	1	1	1	0	0	3	d
874	Cracking	1	1	1	0	0	3	d
875	Cracking	1	1	1	0	0	3	d
876	Cracking	1	1	1	0	0	3	d
877	Cracking	1	1	1	0	0	3	d
878	Cracking	1	1	1	0	0	3	d
879	Cracking	1	1	1	0	0	3	d
880	Cracking	1	1	1	0	0	3	d
881	Cracking	1	1	1	0	0	3	d
882	Cracking	1	1	1	0	0	3	d
883	Delamination	1	1	0	0	0	2	c
884	Delamination	1	1	0	0	0	2	e
885	Cracking	1	0	1	0	0	2	b
886	Spalling	1	0	0	0	0	1	c
887	Spalling	1	0	0	0	0	1	c
888	Cracking	1	1	1	0	0	3	e
889	Cracking	1	1	1	0	0	3	e
890	Cracking	1	1	1	0	0	3	e
891	Cracking	1	0	1	0	0	2	d
892	Cracking	1	0	1	0	0	2	d
893	Cracking	1	1	1	0	0	3	d
894	Cracking	1	1	1	0	0	3	d
895	Spalling	1	0	0	0	0	1	c
896	Cracking	1	1	1	0	0	3	e
897	Cracking	1	1	1	0	0	3	e
898	Cracking	1	1	1	0	0	3	d

Damage Sample	Type of Damage	S	R	K	F	P	NP	P
899	Cracking	1	0	1	0	0	2	d
900	Cracking	1	0	1	0	0	2	d
901	Cracking	1	0	1	0	0	2	d
902	Cracking	1	0	1	0	0	2	c
903	Cracking	1	0	1	0	0	2	c
904	Spalling	1	0	0	0	0	1	c
905	Spalling	1	0	0	0	0	1	c
906	Spalling	1	0	0	0	0	1	c
907	Spalling	1	0	0	0	0	1	c
908	Spalling	1	0	0	0	0	1	c
909	Spalling	1	0	0	0	0	1	c
910	Spalling	1	0	0	0	0	1	c
911	Spalling	1	0	0	0	0	1	c
912	Spalling	1	0	0	0	0	1	c
913	Spalling	1	0	0	0	0	1	c
914	Delamination	1	1	0	0	0	2	e
915	Delamination	1	1	0	0	0	2	d
916	Exposed Rebars	1	1	1	0	0	3	d
917	Spalling	1	0	0	0	0	1	c
918	Spalling	1	0	0	0	0	1	c
919	Exposed Rebars	1	1	1	0	0	3	d
920	Spalling	1	0	0	0	0	1	c
921	Spalling	1	0	0	0	0	1	c
922	Spalling	1	0	0	0	0	1	c
923	Exposed Rebars	1	1	1	0	0	3	d
924	Spalling	1	0	0	0	0	1	c
925	Spalling	1	0	0	0	0	1	c
926	Exposed Rebars	1	1	0	0	0	2	d
927	Exposed Rebars	1	1	0	0	0	2	d
928	Spalling	1	0	0	0	0	1	d
929	Spalling	1	0	0	0	0	1	d
930	Exposed Rebars	1	1	0	0	0	2	d
931	Exposed Rebars	1	1	0	0	0	2	d
932	Exposed Rebars	1	1	0	0	0	2	d
933	Exposed Rebars	1	1	0	0	0	2	d
934	Exposed Rebars	1	1	0	0	0	2	d
935	Cracking	1	0	1	0	0	2	d
936	Cracking	1	0	1	0	0	2	d
937	Cracking	1	0	1	0	0	2	d
938	Cracking	1	0	1	0	0	2	d
939	Cracking	1	0	1	0	0	2	d
940	Cracking	1	0	1	0	0	2	d
941	Cracking	1	0	1	0	0	2	d
942	Cracking	1	0	1	0	0	2	d
943	Cracking	1	0	1	0	0	2	d

Damage Sample	Type of Damage	S	R	K	F	P	NP	P
944	Cracking	1	0	1	0	0	2	d
945	Cracking	1	1	1	0	0	3	d
946	Cracking	1	1	1	0	0	3	d
947	Cracking	1	1	1	0	0	3	d
948	Cracking	1	1	1	0	0	3	d
949	Cracking	1	1	1	0	0	3	d
950	Cracking	1	1	1	0	0	3	d
951	Cracking	1	1	1	0	0	3	d
952	Cracking	1	1	1	0	0	3	d
953	Cracking	1	0	0	0	0	1	b
954	Cracking	1	0	0	0	0	1	b
955	Cracking	1	0	1	0	0	2	d
956	Cracking	1	0	1	0	0	2	d
957	Exposed Rebars	1	1	0	0	0	2	d
958	Exposed Rebars	1	1	0	0	0	2	d
959	Spalling	1	0	0	0	0	1	c
960	Spalling	1	0	0	0	0	1	c
961	Exposed Rebars	1	1	0	0	0	2	d
962	Exposed Rebars	1	1	0	0	0	2	d
963	Exposed Rebars	1	1	0	0	0	2	d
964	Exposed Rebars	1	1	0	0	0	2	d
965	Exposed Rebars	1	1	0	0	0	2	d
966	Exposed Rebars	1	1	0	0	0	2	d
967	Exposed Rebars	1	1	0	0	0	2	d
968	Exposed Rebars	1	1	0	0	0	2	d
969	Exposed Rebars	1	1	0	0	0	2	d
970	Exposed Rebars	1	1	0	0	0	2	d
971	Exposed Rebars	1	1	0	0	0	2	d
972	Exposed Rebars	1	1	0	0	0	2	d
973	Delamination	1	0	0	0	0	1	c
974	Delamination	1	0	0	0	0	1	c
975	Delamination	1	0	0	0	0	1	c
976	Delamination	1	0	0	0	0	1	c
977	Exposed Rebars	1	1	0	0	0	2	d
978	Exposed Rebars	1	1	0	0	0	2	d
979	Exposed Rebars	1	1	0	0	0	2	d
980	Exposed Rebars	1	1	0	0	0	2	d
981	Spalling	1	0	0	0	0	1	c
982	Spalling	1	0	0	0	0	1	c
983	Spalling	1	1	0	0	0	2	d
984	Spalling	1	1	0	0	0	2	d
985	Exposed Rebars	1	1	0	0	0	2	d
986	Exposed Rebars	1	1	0	0	0	2	d
987	Spalling	1	1	0	0	0	2	d
988	Spalling	1	1	0	0	0	2	d

Damage Sample	Type of Damage	S	R	K	F	P	NP	P
989	Cracking	1	0	1	0	0	2	d
990	Cracking	1	0	1	0	0	2	d
991	Cracking	1	0	1	0	0	2	c
992	Cracking	1	0	1	0	0	2	c
993	Cracking	1	0	1	0	0	2	c
994	Cracking	1	0	1	0	0	2	c
995	Spalling	1	1	0	0	0	2	d
996	Spalling	1	1	0	0	0	2	d
997	Exposed Rebars	1	1	0	0	0	2	d
998	Exposed Rebars	1	1	0	0	0	2	d
999	Exposed Rebars	1	1	0	0	0	2	d
1000	Exposed Rebars	1	1	0	0	0	2	d
1001	Exposed Rebars	1	1	0	0	0	2	d
1002	Exposed Rebars	1	1	0	0	0	2	d
1003	Exposed Rebars	1	1	0	0	0	2	d
1004	Exposed Rebars	1	1	0	0	0	2	d

Steel Girder Bridge Damage Sample

Damage Sample	Type of Damage	S	R	K	F	P	NP	P
1	Corrosion	1	1	0	0	0	2	b
2	Coating	1	0	1	0	0	2	e
3	Corrosion	1	1	0	0	0	2	b
4	Corrosion	1	1	0	0	0	2	b
5	Coating	1	0	1	0	0	2	e
6	Corrosion	1	1	0	0	0	2	b
7	Corrosion	1	1	0	0	0	2	b
8	Corrosion	1	1	0	0	0	2	b
9	Corrosion	1	1	0	0	0	2	b
10	Corrosion	1	1	0	0	0	2	b
11	Corrosion	1	1	0	0	0	2	b
12	Corrosion	1	1	0	0	0	2	b
13	Corrosion	1	1	0	0	0	2	b
14	Corrosion	1	1	0	0	0	2	b
15	Coating	1	0	1	0	0	2	e
16	Coating	1	0	1	0	0	2	e
17	Coating	1	0	1	0	0	2	e
18	Corrosion	1	1	0	0	0	2	b
19	Corrosion	1	1	0	0	0	2	b
20	Coating	1	0	1	0	0	2	e
21	Coating	1	0	1	0	0	2	e
22	Coating	1	0	1	0	0	2	e
23	Coating	1	0	1	0	0	2	e
24	Coating	1	0	1	0	0	2	e
25	Corrosion	1	1	0	0	0	2	b
26	Corrosion	1	1	0	0	0	2	d
27	Corrosion	1	1	0	0	0	2	d
28	Corrosion	1	1	0	0	0	2	d
29	Corrosion	1	1	0	0	0	2	d
30	Coating	1	0	0	0	0	1	e
31	Coating	1	0	0	0	0	1	e
32	Coating	1	0	1	0	0	2	e
33	Coating	1	0	1	0	0	2	e
34	Coating	1	0	1	0	0	2	e
35	Coating	1	0	1	0	0	2	e
36	Coating	1	0	1	0	0	2	e
37	Coating	1	0	1	0	0	2	e
38	Coating	1	0	1	0	0	2	e
39	Coating	1	0	1	0	0	2	e
40	Coating	1	0	1	0	0	2	e
41	Coating	1	0	1	0	0	2	e
42	Coating	1	0	1	0	0	2	e
43	Corrosion	1	1	0	0	0	2	b
44	Coating	1	0	1	0	0	2	e

Damage Sample	Type of Damage	S	R	K	F	P	NP	P
45	Coating	1	0	1	0	0	2	e
46	Coating	1	0	1	0	0	2	e
47	Corrosion	1	1	0	0	0	2	b
48	Corrosion	1	1	0	0	0	2	b
49	Corrosion	1	1	0	0	0	2	b
50	Coating	1	0	1	0	0	2	e
51	Coating	1	0	1	0	0	2	e
52	Coating	1	0	1	0	0	2	e
53	Corrosion	1	1	0	0	0	2	b
54	Coating	1	0	1	0	0	2	e
55	Corrosion	1	1	1	0	0	3	d
56	Corrosion	1	1	0	0	0	2	d
57	Deformation	1	1	0	0	0	2	c
58	Corrosion	1	1	1	0	0	3	d
59	Corrosion	1	1	0	0	0	2	d
60	Corrosion	1	1	0	0	0	2	d
61	Corrosion	1	1	1	0	0	3	d
62	Corrosion	1	1	1	0	0	3	d
63	Corrosion	1	1	1	0	0	3	d
64	Corrosion	1	1	1	0	0	3	d
65	Corrosion	1	1	0	0	0	2	d
66	Corrosion	1	1	1	0	0	3	d
67	Corrosion	1	1	1	0	0	3	d
68	Corrosion	1	1	1	0	0	3	d
69	Corrosion	1	1	1	0	0	3	d
70	Corrosion	1	1	1	0	0	3	d
71	Corrosion	1	1	0	0	0	2	b
72	Corrosion	1	1	1	0	0	3	d
73	Corrosion	1	1	1	0	0	3	d
74	Corrosion	1	1	1	0	0	3	d
75	Corrosion	1	1	1	0	0	3	d
76	Corrosion	1	1	1	0	0	3	d
77	Corrosion	1	1	1	0	0	3	d
78	Corrosion	1	1	1	0	0	3	d
79	Corrosion	1	1	0	0	0	2	b
80	Corrosion	1	1	0	0	0	2	b
81	Corrosion	1	1	0	0	0	2	b
82	Corrosion	1	1	1	0	0	3	d
83	Corrosion	1	1	1	0	0	3	d
84	Corrosion	1	1	1	0	0	3	d
85	Corrosion	1	1	1	0	0	3	d
86	Corrosion	1	1	1	0	0	3	d
87	Corrosion	1	1	1	0	0	3	d
88	Corrosion	1	1	1	0	0	3	d
89	Corrosion	1	1	1	0	0	3	d

Damage Sample	Type of Damage	S	R	K	F	P	NP	P
90	Corrosion	1	1	1	0	0	3	d
91	Corrosion	1	1	1	0	0	3	d
92	Corrosion	1	1	1	0	0	3	c
93	Corrosion	1	1	0	0	0	2	d
94	Corrosion	1	1	0	0	0	2	d
95	Corrosion	1	1	0	0	0	2	d
96	Corrosion	1	1	0	0	0	2	d
97	Corrosion	1	1	0	0	0	2	b
98	Corrosion	1	1	0	0	0	2	b
99	Corrosion	1	1	0	0	0	2	b
100	Corrosion	1	1	0	0	0	2	d
101	Corrosion	1	1	0	0	0	2	b
102	Corrosion	1	1	0	0	0	2	b
103	Corrosion	1	0	0	0	0	1	a
104	Corrosion	1	1	0	0	0	2	a
105	Deformation	1	1	0	0	0	2	c
106	Deformation	1	1	0	0	0	2	c
107	Corrosion	1	1	0	0	0	2	a
108	Corrosion	1	1	1	0	0	3	a
109	Deformation	1	1	0	0	0	2	c
110	Corrosion	1	1	0	0	0	2	b
111	Deformation	1	1	0	0	0	2	c
112	Coating	1	1	1	0	0	3	c
113	Coating	1	1	1	0	0	3	c
114	Coating	1	1	0	0	0	2	c
115	Coating	1	1	1	0	0	3	c
116	Coating	1	0	1	0	0	2	c
117	Coating	1	0	1	0	0	2	c
118	Coating	1	0	1	0	0	2	c
119	Corrosion	1	0	0	0	0	1	b
120	Coating	1	0	1	0	0	2	c
121	Coating	1	0	1	0	0	2	c
122	Coating	1	0	1	0	0	2	c
123	Coating	1	0	1	0	0	2	c
124	Coating	1	0	1	0	0	2	c
125	Corrosion	1	1	0	0	0	2	b
126	Coating	1	0	1	0	0	2	c
127	Coating	1	0	1	0	0	2	c
128	Crack	1	1	1	0	0	3	d
129	Crack	1	1	1	0	0	3	d
130	Crack	1	1	1	0	0	3	d
131	Corrosion	1	1	0	0	0	2	b
132	Coating	1	0	1	0	0	2	c
133	Corrosion	1	1	0	0	0	2	b
134	Corrosion	1	1	0	0	0	2	b

Damage Sample	Type of Damage	S	R	K	F	P	NP	P
135	Corrosion	1	1	0	0	0	2	b
136	Corrosion	1	1	0	0	0	2	b
137	Corrosion	1	1	0	0	0	2	b
138	Corrosion	1	1	0	0	0	2	b
139	Coating	1	0	1	0	0	2	c
140	Coating	1	0	1	0	0	2	c
141	Corrosion	1	1	0	0	0	2	b
142	Coating	1	1	1	0	0	3	e
143	Coating	1	1	1	0	0	3	e
144	Coating	1	0	1	0	0	2	c
145	Coating	1	1	1	0	0	3	d
146	Coating	1	0	1	0	0	2	a
147	Corrosion	1	1	0	0	0	2	a
148	Corrosion	1	1	0	0	0	2	a
149	Corrosion	1	1	0	0	0	2	a
150	Corrosion	1	1	0	0	0	2	a
151	Corrosion	1	1	1	0	0	3	e
152	Corrosion	1	1	1	0	0	3	e
153	Corrosion	1	1	1	0	0	3	e
154	Corrosion	1	1	0	0	0	2	b
155	Coating	1	1	1	0	0	3	e
156	Coating	1	1	1	0	0	3	e
157	Corrosion	1	1	0	0	0	2	b
158	Corrosion	1	1	0	0	0	2	b
159	Corrosion	1	1	0	0	0	2	b
160	Deformation	1	1	0	0	0	2	c
161	Coating	1	1	1	0	0	3	e
162	Coating	1	1	1	0	0	3	e
163	Coating	1	1	1	0	0	3	e
164	Coating	1	1	1	0	0	3	e
165	Coating	1	1	1	0	0	3	e
166	Deformation	1	1	0	0	0	2	c
167	Corrosion	1	1	1	0	0	3	d
168	Corrosion	1	1	0	0	0	2	d
169	Coating	1	0	1	0	0	2	e
170	Coating	1	0	1	0	0	2	e
171	Coating	1	0	1	0	0	2	e
172	Corrosion	1	1	0	0	0	2	c
173	Corrosion	1	1	0	0	0	2	c
174	Coating	1	0	1	0	0	2	c
175	Coating	1	0	1	0	0	2	c
176	Coating	1	0	1	0	0	2	c
177	Coating	1	0	1	0	0	2	c
178	Corrosion	1	1	1	0	0	3	e
179	Corrosion	1	1	1	0	0	3	e

Damage Sample	Type of Damage	S	R	K	F	P	NP	P
180	Corrosion	1	1	1	0	0	3	e
181	Coating	1	1	1	0	0	3	d
182	Coating	1	1	1	0	0	3	c
183	Coating	1	1	1	0	0	3	d
184	Coating	1	1	1	0	0	3	e
185	Corrosion	1	1	1	0	0	3	e
186	Coating	1	1	1	0	0	3	e
187	Coating	1	1	1	0	0	3	d
188	Coating	1	0	1	0	0	2	e
189	Coating	1	0	1	0	0	2	e
190	Coating	1	0	1	0	0	2	e
191	Coating	1	0	1	0	0	2	e
192	Coating	1	0	1	0	0	2	e
193	Coating	1	0	1	0	0	2	e
194	Coating	1	0	1	0	0	2	e
195	Corrosion	1	1	0	0	0	2	b
196	Corrosion	1	1	0	0	0	2	b
197	Coating	1	0	1	0	0	2	e
198	Coating	1	0	1	0	0	2	e
199	Coating	1	0	1	0	0	2	d
200	Coating	1	0	1	0	0	2	c
201	Coating	1	0	1	0	0	2	c
202	Coating	1	0	1	0	0	2	c
203	Coating	1	0	1	0	0	2	c
204	Coating	1	0	1	0	0	2	e
205	Coating	1	0	1	0	0	2	e
206	Coating	1	0	1	0	0	2	e
207	Coating	1	0	1	0	0	2	e
208	Coating	1	0	1	0	0	2	e
209	Coating	1	0	1	0	0	2	e
210	Coating	1	0	1	0	0	2	c
211	Coating	1	0	1	0	0	2	c
212	Corrosion	1	1	0	0	0	2	b
213	Coating	1	0	1	0	0	2	e
214	Corrosion	1	1	0	0	0	2	b
215	Coating	1	0	1	0	0	2	e
216	Corrosion	1	1	0	0	0	2	b
217	Coating	1	0	1	0	0	2	e
218	Coating	1	0	1	0	0	2	e
219	Coating	1	0	1	0	0	2	e
220	Corrosion	1	1	0	0	0	2	b
221	Coating	1	0	1	0	0	2	e
222	Coating	1	0	1	0	0	2	e
223	Coating	1	0	1	0	0	2	e
224	Corrosion	1	1	0	0	0	2	b

Damage Sample	Type of Damage	S	R	K	F	P	NP	P
225	Coating	1	0	1	0	0	2	e
226	Corrosion	1	1	0	0	0	2	b
227	Coating	1	0	1	0	0	2	e
228	Corrosion	1	1	0	0	0	2	b
229	Coating	1	0	1	0	0	2	e
230	Corrosion	1	1	0	0	0	2	b
231	Coating	1	0	1	0	0	2	e
232	Corrosion	1	1	0	0	0	2	b
233	Coating	1	0	1	0	0	2	e
234	Corrosion	1	1	0	0	0	2	c
235	Corrosion	1	1	0	0	0	2	c
236	Coating	1	0	1	0	0	2	e
237	Corrosion	1	1	0	0	0	2	c
238	Coating	1	0	1	0	0	2	e
239	Coating	1	0	1	0	0	2	e
240	Corrosion	1	1	0	0	0	2	c
241	Coating	1	0	1	0	0	2	e
242	Corrosion	1	1	0	0	0	2	c
243	Coating	1	0	1	0	0	2	e
244	Corrosion	1	1	0	0	0	2	c
245	Coating	1	0	1	0	0	2	e
246	Corrosion	1	1	0	0	0	2	c
247	Coating	1	0	1	0	0	2	e
248	Coating	1	0	1	0	0	2	e
249	Coating	1	0	1	0	0	2	e
250	Corrosion	1	1	0	0	0	2	c
251	Coating	1	0	1	0	0	2	e
252	Coating	1	0	1	0	0	2	e
253	Coating	1	0	1	0	0	2	e
254	Coating	1	0	1	0	0	2	e
255	Corrosion	1	1	0	0	0	2	b
256	Corrosion	1	1	0	0	0	2	b
257	Corrosion	1	1	0	0	0	2	b
258	Corrosion	1	1	0	0	0	2	b
259	Corrosion	1	1	0	0	0	2	b
260	Corrosion	1	1	0	0	0	2	b
261	Coating	1	0	1	0	0	2	e
262	Coating	1	0	1	0	0	2	e
263	Coating	1	0	1	0	0	2	e
264	Corrosion	1	1	0	0	0	2	d
265	Corrosion	1	1	1	0	0	3	d
266	Coating	1	0	1	0	0	2	e
267	Coating	1	0	1	0	0	2	e
268	Coating	1	0	1	0	0	2	e
269	Corrosion	1	1	0	0	0	2	b

Damage Sample	Type of Damage	S	R	K	F	P	NP	P
270	Corrosion	1	1	0	0	0	2	d
271	Corrosion	1	1	1	0	0	3	d
272	Corrosion	1	1	1	0	0	3	d
273	Coating	1	0	1	0	0	2	e
274	Coating	1	0	1	0	0	2	e
275	Corrosion	1	1	1	0	0	3	d
276	Corrosion	1	1	1	0	0	3	d
277	Corrosion	1	1	1	0	0	3	d
278	Corrosion	1	1	0	0	0	2	b
279	Corrosion	1	1	0	0	0	2	d
280	Corrosion	1	1	0	0	0	2	d
281	Coating	1	0	1	0	0	2	c
282	Corrosion	1	1	0	0	0	2	d
283	Corrosion	1	1	0	0	0	2	d
284	Coating	1	0	1	0	0	2	c
285	Corrosion	1	1	0	0	0	2	b
286	Corrosion	1	1	0	0	0	2	b
287	Coating	1	0	1	0	0	2	c
288	Coating	1	0	1	0	0	2	c
289	Coating	1	0	1	0	0	2	c
290	Corrosion	1	1	0	0	0	2	b
291	Corrosion	1	1	0	0	0	2	d
292	Corrosion	1	1	0	0	0	2	d
293	Corrosion	1	1	0	0	0	2	d
294	Corrosion	1	1	0	0	0	2	d
295	Corrosion	1	1	0	0	0	2	d
296	Corrosion	1	1	0	0	0	2	d
297	Corrosion	1	1	0	0	0	2	d
298	Coating	1	0	1	0	0	2	d
299	Corrosion	1	1	0	0	0	2	d
300	Corrosion	1	1	0	0	0	2	b
301	Corrosion	1	1	0	0	0	2	d
302	Corrosion	1	1	0	0	0	2	d
303	Coating	1	0	1	0	0	2	d
304	Corrosion	1	1	0	0	0	2	d
305	Coating	1	0	1	0	0	2	e
306	Corrosion	1	1	0	0	0	2	d
307	Coating	1	0	1	0	0	2	e
308	Coating	1	0	1	0	0	2	e
309	Corrosion	1	1	0	0	0	2	d
310	Coating	1	0	1	0	0	2	e
311	Coating	1	0	1	0	0	2	c
312	Corrosion	1	1	0	0	0	2	d
313	Coating	1	0	1	0	0	2	c
314	Coating	1	0	1	0	0	2	c

Damage Sample	Type of Damage	S	R	K	F	P	NP	P
315	Corrosion	1	1	0	0	0	2	d
316	Coating	1	0	1	0	0	2	e
317	Coating	1	0	1	0	0	2	c
318	Coating	1	0	1	0	0	2	e
319	Coating	1	0	1	0	0	2	e
320	Corrosion	1	1	0	0	0	2	d
321	Coating	1	0	1	0	0	2	c
322	Coating	1	0	1	0	0	2	c
323	Coating	1	0	1	0	0	2	e
324	Coating	1	0	1	0	0	2	c
325	Corrosion	1	1	0	0	0	2	d
326	Coating	1	0	1	0	0	2	c
327	Coating	1	0	1	0	0	2	c
328	Coating	1	0	1	0	0	2	e
329	Coating	1	0	1	0	0	2	e
330	Coating	1	0	1	0	0	2	c
331	Coating	1	0	1	0	0	2	e
332	Coating	1	0	1	0	0	2	c
333	Coating	1	0	1	0	0	2	c
334	Coating	1	0	1	0	0	2	e
335	Coating	1	0	1	0	0	2	e
336	Coating	1	0	1	0	0	2	c
337	Coating	1	0	1	0	0	2	e
338	Corrosion	1	1	0	0	0	2	b
339	Corrosion	1	1	0	0	0	2	b
340	Corrosion	1	1	0	0	0	2	d
341	Corrosion	1	1	0	0	0	2	d
342	Corrosion	1	1	0	0	0	2	d
343	Corrosion	1	1	0	0	0	2	d
344	Corrosion	1	1	0	0	0	2	d
345	Corrosion	1	1	0	0	0	2	d
346	Coating	1	0	1	0	0	2	e
347	Coating	1	0	1	0	0	2	e
348	Coating	1	0	1	0	0	2	e
349	Coating	1	0	1	0	0	2	e
350	Coating	1	0	1	0	0	2	e
351	Coating	1	0	1	0	0	2	d
352	Coating	1	0	1	0	0	2	d
353	Coating	1	0	1	0	0	2	d
354	Coating	1	0	1	0	0	2	d
355	Coating	1	0	1	0	0	2	d
356	Coating	1	0	1	0	0	2	d
357	Coating	1	0	1	0	0	2	d
358	Coating	1	0	1	0	0	2	e
359	Coating	1	0	1	0	0	2	e

Damage Sample	Type of Damage	S	R	K	F	P	NP	P
360	Coating	1	0	1	0	0	2	e
361	Coating	1	0	1	0	0	2	e
362	Coating	1	0	1	0	0	2	e
363	Coating	1	0	1	0	0	2	e
364	Coating	1	0	1	0	0	2	e
365	Coating	1	0	1	0	0	2	e
366	Coating	1	0	1	0	0	2	e
367	Coating	1	0	1	0	0	2	e
368	Coating	1	0	1	0	0	2	e
369	Coating	1	0	1	0	0	2	e
370	Coating	1	0	1	0	0	2	e
371	Corrosion	1	1	0	0	0	2	d
372	Corrosion	1	1	0	0	0	2	d
373	Coating	1	0	1	0	0	2	e
374	Coating	1	0	1	0	0	2	e
375	Coating	1	0	1	0	0	2	e
376	Coating	1	0	1	0	0	2	e
377	Coating	1	0	1	0	0	2	e
378	Coating	1	0	1	0	0	2	e
379	Coating	1	0	1	0	0	2	e
380	Coating	1	0	1	0	0	2	e
381	Coating	1	0	1	0	0	2	e
382	Coating	1	0	1	0	0	2	e
383	Coating	1	0	1	0	0	2	e
384	Coating	1	0	1	0	0	2	e
385	Coating	1	0	1	0	0	2	e
386	Coating	1	0	1	0	0	2	e
387	Coating	1	0	1	0	0	2	e
388	Coating	1	0	1	0	0	2	e
389	Coating	1	0	1	0	0	2	e
390	Coating	1	0	1	0	0	2	e
391	Coating	1	0	1	0	0	2	e
392	Coating	1	0	1	0	0	2	e
393	Coating	1	0	1	0	0	2	e
394	Coating	1	0	1	0	0	2	e
395	Coating	1	0	1	0	0	2	e
396	Coating	1	0	1	0	0	2	e
397	Coating	1	0	1	0	0	2	e
398	Corrosion	1	1	0	0	0	2	d
399	Corrosion	1	1	0	0	0	2	d
400	Coating	1	0	1	0	0	2	e
401	Coating	1	0	1	0	0	2	e
402	Coating	1	0	1	0	0	2	e
403	Coating	1	0	1	0	0	2	e
404	Coating	1	0	1	0	0	2	e

Damage Sample	Type of Damage	S	R	K	F	P	NP	P
405	Coating	1	0	1	0	0	2	e
406	Coating	1	0	1	0	0	2	e
407	Coating	1	0	1	0	0	2	e
408	Coating	1	0	1	0	0	2	e
409	Coating	1	0	1	0	0	2	c
410	Coating	1	0	1	0	0	2	c
411	Coating	1	0	1	0	0	2	c
412	Coating	1	0	1	0	0	2	c
413	Coating	1	0	1	0	0	2	c
414	Coating	1	0	1	0	0	2	c
415	Coating	1	0	1	0	0	2	d
416	Coating	1	0	1	0	0	2	d
417	Coating	1	0	1	0	0	2	c
418	Coating	1	0	1	0	0	2	c
419	Coating	1	0	1	0	0	2	c
420	Coating	1	0	1	0	0	2	c
421	Coating	1	0	1	0	0	2	c
422	Coating	1	0	1	0	0	2	c
423	Coating	1	0	1	0	0	2	c
424	Coating	1	0	1	0	0	2	c
425	Coating	1	0	1	0	0	2	c
426	Coating	1	0	1	0	0	2	c
427	Coating	1	0	1	0	0	2	e
428	Coating	1	0	1	0	0	2	e
429	Coating	1	0	1	0	0	2	c
430	Coating	1	0	1	0	0	2	c
431	Corrosion	1	1	0	0	0	2	d
432	Corrosion	1	1	0	0	0	2	d
433	Coating	1	0	1	0	0	2	c
434	Coating	1	0	1	0	0	2	c
435	Coating	1	0	1	0	0	2	c
436	Coating	1	0	1	0	0	2	c
437	Coating	1	0	1	0	0	2	c
438	Coating	1	0	1	0	0	2	c
439	Corrosion	1	1	0	0	0	2	e
440	Corrosion	1	1	0	0	0	2	e
441	Corrosion	1	1	1	0	0	3	e
442	Corrosion	1	1	0	0	0	2	e
443	Corrosion	1	1	1	0	0	3	e
444	Corrosion	1	1	0	0	0	2	b
445	Corrosion	1	1	0	0	0	2	b
446	Coating	1	0	1	0	0	2	c
447	Coating	1	0	1	0	0	2	c
448	Coating	1	0	1	0	0	2	c
449	Coating	1	0	1	0	0	2	c

Damage Sample	Type of Damage	S	R	K	F	P	NP	P
450	Coating	1	0	1	0	0	2	c
451	Coating	1	0	1	0	0	2	c
452	Corrosion	1	1	1	0	0	3	d
453	Corrosion	1	1	1	0	0	3	d
454	Corrosion	1	1	1	0	0	3	d
455	Coating	1	0	1	0	0	2	c
456	Coating	1	0	1	0	0	2	c
457	Corrosion	1	1	0	0	0	2	d
458	Corrosion	1	1	0	0	0	2	d
459	Corrosion	1	1	0	0	0	2	d
460	Corrosion	1	1	0	0	0	2	d
461	Coating	1	0	1	0	0	2	c
462	Coating	1	0	1	0	0	2	c
463	Coating	1	0	1	0	0	2	c
464	Coating	1	0	1	0	0	2	c
465	Corrosion	1	1	0	0	0	2	e
466	Corrosion	1	1	1	0	0	3	e
467	Corrosion	1	1	1	0	0	3	e
468	Corrosion	1	1	1	0	0	3	e
469	Corrosion	1	1	1	0	0	3	e
470	Corrosion	1	1	1	0	0	3	e
471	Corrosion	1	1	1	0	0	3	e
472	Corrosion	1	1	1	0	0	3	e
473	Corrosion	1	1	1	0	0	3	e
474	Coating	1	0	1	0	0	2	d
475	Coating	1	0	1	0	0	2	d
476	Coating	1	0	1	0	0	2	c
477	Coating	1	0	1	0	0	2	c
478	Coating	1	0	1	0	0	2	c
479	Coating	1	0	1	0	0	2	c
480	Coating	1	0	1	0	0	2	c
481	Coating	1	0	1	0	0	2	c
482	Coating	1	0	1	0	0	2	c
483	Coating	1	0	1	0	0	2	c
484	Coating	1	0	1	0	0	2	c
485	Coating	1	0	1	0	0	2	c
486	Coating	1	0	1	0	0	2	c
487	Coating	1	0	1	0	0	2	c
488	Coating	1	0	1	0	0	2	c
489	Coating	1	0	1	0	0	2	c
490	Coating	1	0	1	0	0	2	c
491	Coating	1	0	1	0	0	2	c
492	Coating	1	0	1	0	0	2	c
493	Coating	1	0	1	0	0	2	c
494	Coating	1	0	1	0	0	2	c

Damage Sample	Type of Damage	S	R	K	F	P	NP	P
495	Coating	1	0	1	0	0	2	c
496	Coating	1	0	1	0	0	2	c
497	Corrosion	1	1	0	0	0	2	c
498	Corrosion	1	1	0	0	0	2	c
499	Coating	1	0	1	0	0	2	e
500	Coating	1	0	1	0	0	2	e
501	Corrosion	1	1	0	0	0	2	c
502	Corrosion	1	1	0	0	0	2	c
503	Coating	1	0	1	0	0	2	e
504	Coating	1	0	1	0	0	2	c
505	Coating	1	0	1	0	0	2	c
506	Coating	1	0	1	0	0	2	c
507	Coating	1	0	1	0	0	2	c
508	Coating	1	0	1	0	0	2	c
509	Coating	1	0	1	0	0	2	c
510	Coating	1	0	1	0	0	2	c
511	Coating	1	0	1	0	0	2	c
512	Coating	1	0	1	0	0	2	c
513	Coating	1	0	1	0	0	2	c
514	Coating	1	0	1	0	0	2	c
515	Coating	1	0	1	0	0	2	c
516	Coating	1	0	1	0	0	2	c
517	Coating	1	0	1	0	0	2	c
518	Coating	1	0	1	0	0	2	c
519	Coating	1	0	1	0	0	2	c
520	Coating	1	0	1	0	0	2	c
521	Coating	1	0	1	0	0	2	c
522	Coating	1	0	1	0	0	2	c
523	Coating	1	0	1	0	0	2	c
524	Coating	1	0	1	0	0	2	c
525	Coating	1	0	1	0	0	2	c
526	Coating	1	0	1	0	0	2	c
527	Coating	1	0	1	0	0	2	c
528	Corrosion	1	1	0	0	0	2	c
529	Corrosion	1	1	0	0	0	2	c
530	Coating	1	0	1	0	0	2	e
531	Coating	1	0	1	0	0	2	e
532	Coating	1	0	1	0	0	2	c
533	Coating	1	0	1	0	0	2	c
534	Coating	1	0	1	0	0	2	c
535	Coating	1	0	1	0	0	2	c
536	Coating	1	0	1	0	0	2	c
537	Coating	1	0	1	0	0	2	c
538	Coating	1	0	1	0	0	2	c
539	Coating	1	0	1	0	0	2	c

Damage Sample	Type of Damage	S	R	K	F	P	NP	P
540	Coating	1	0	1	0	0	2	c
541	Coating	1	0	1	0	0	2	c
542	Coating	1	0	1	0	0	2	c
543	Coating	1	0	1	0	0	2	c
544	Coating	1	0	1	0	0	2	c
545	Coating	1	0	1	0	0	2	c
546	Coating	1	0	1	0	0	2	c
547	Coating	1	0	1	0	0	2	c
548	Coating	1	0	1	0	0	2	c
549	Coating	1	0	1	0	0	2	c
550	Coating	1	0	1	0	0	2	e
551	Coating	1	0	1	0	0	2	e
552	Coating	1	0	1	0	0	2	c
553	Coating	1	0	1	0	0	2	c
554	Coating	1	0	1	0	0	2	c
555	Coating	1	0	1	0	0	2	c
556	Coating	1	0	1	0	0	2	c
557	Coating	1	0	1	0	0	2	c
558	Coating	1	0	1	0	0	2	c
559	Coating	1	0	1	0	0	2	c
560	Corrosion	1	0	0	0	0	1	b
561	Corrosion	1	1	0	0	0	2	b
562	Coating	1	0	1	0	0	2	e
563	Coating	1	0	1	0	0	2	e
564	Coating	1	0	1	0	0	2	c
565	Coating	1	0	1	0	0	2	c
566	Coating	1	0	1	0	0	2	c
567	Coating	1	0	1	0	0	2	c
568	Coating	1	0	1	0	0	2	c
569	Coating	1	0	1	0	0	2	c
570	Coating	1	0	1	0	0	2	c
571	Coating	1	0	1	0	0	2	c
572	Corrosion	1	1	0	0	0	2	d
573	Corrosion	1	1	0	0	0	2	d
574	Corrosion	1	1	0	0	0	2	d
575	Corrosion	1	1	0	0	0	2	d
576	Coating	1	0	1	0	0	2	e
577	Coating	1	0	1	0	0	2	e
578	Coating	1	0	1	0	0	2	d
579	Coating	1	0	1	0	0	2	d
580	Coating	1	0	1	0	0	2	c
581	Coating	1	0	1	0	0	2	c
582	Coating	1	0	1	0	0	2	c
583	Coating	1	0	1	0	0	2	c
584	Corrosion	1	1	0	0	0	2	b

Damage Sample	Type of Damage	S	R	K	F	P	NP	P
585	Corrosion	1	1	0	0	0	2	b
586	Coating	1	0	1	0	0	2	e
587	Coating	1	0	1	0	0	2	e
588	Corrosion	1	1	0	0	0	2	b
589	Corrosion	1	1	0	0	0	2	b
590	Coating	1	0	1	0	0	2	d
591	Coating	1	0	1	0	0	2	d
592	Coating	1	0	1	0	0	2	d
593	Coating	1	0	1	0	0	2	d
594	Corrosion	1	1	1	0	0	3	d
595	Coating	1	0	1	0	0	2	c
596	Corrosion	1	1	1	0	0	3	d
597	Corrosion	1	1	0	0	0	2	b
598	Corrosion	1	1	0	0	0	2	b
599	Coating	1	0	1	0	0	2	e
600	Coating	1	0	1	0	0	2	e
601	Coating	1	0	1	0	0	2	e
602	Coating	1	0	1	0	0	2	e
603	Corrosion	1	1	0	0	0	2	d
604	Corrosion	1	1	0	0	0	2	d
605	Corrosion	1	1	0	0	0	2	b
606	Coating	1	0	1	0	0	2	e
607	Coating	1	0	1	0	0	2	e
608	Coating	1	0	1	0	0	2	c
609	Coating	1	0	1	0	0	2	c
610	Coating	1	0	1	0	0	2	c
611	Coating	1	0	1	0	0	2	c
612	Coating	1	0	1	0	0	2	c
613	Coating	1	0	1	0	0	2	c
614	Corrosion	1	1	0	0	0	2	b
615	Corrosion	1	1	0	0	0	2	b
616	Coating	1	0	1	0	0	2	e
617	Coating	1	0	1	0	0	2	e
618	Coating	1	0	1	0	0	2	c
619	Coating	1	0	1	0	0	2	c
620	Coating	1	0	1	0	0	2	c
621	Coating	1	0	1	0	0	2	c
622	Coating	1	0	1	0	0	2	d
623	Coating	1	0	1	0	0	2	d
624	Corrosion	1	1	1	0	0	3	d
625	Corrosion	1	1	1	0	0	3	d
626	Corrosion	1	1	0	0	0	2	d
627	Corrosion	1	1	0	0	0	2	d
628	Coating	1	0	1	0	0	2	e
629	Coating	1	0	1	0	0	2	e

Damage Sample	Type of Damage	S	R	K	F	P	NP	P
630	Corrosion	1	1	0	0	0	2	d
631	Corrosion	1	1	0	0	0	2	d
632	Corrosion	1	1	0	0	0	2	d
633	Corrosion	1	1	0	0	0	2	d
634	Coating	1	1	1	0	0	3	e
635	Coating	1	1	1	0	0	3	e
636	Coating	1	1	1	0	0	3	e
637	Coating	1	1	1	0	0	3	e
638	Coating	1	1	1	0	0	3	c
639	Coating	1	1	1	0	0	3	c
640	Coating	1	1	1	0	0	3	c
641	Coating	1	1	1	0	0	3	c
642	Coating	1	0	1	0	0	2	c
643	Coating	1	0	1	0	0	2	c
644	Coating	1	0	1	0	0	2	c
645	Coating	1	0	1	0	0	2	c
646	Coating	1	0	1	0	0	2	c
647	Coating	1	0	1	0	0	2	c
648	Coating	1	0	1	0	0	2	c
649	Coating	1	0	1	0	0	2	c
650	Coating	1	0	1	0	0	2	c
651	Coating	1	0	1	0	0	2	c
652	Coating	1	0	1	0	0	2	c
653	Coating	1	0	1	0	0	2	c
654	Coating	1	0	1	0	0	2	c
655	Coating	1	0	1	0	0	2	c
656	Coating	1	0	1	0	0	2	c
657	Coating	1	0	1	0	0	2	c
658	Coating	1	0	1	0	0	2	c
659	Coating	1	0	1	0	0	2	c
660	Coating	1	0	1	0	0	2	c
661	Coating	1	0	1	0	0	2	c
662	Coating	1	0	1	0	0	2	c
663	Coating	1	0	1	0	0	2	c
664	Coating	1	0	1	0	0	2	c
665	Coating	1	0	1	0	0	2	c
666	Coating	1	0	1	0	0	2	c
667	Coating	1	0	1	0	0	2	c
668	Coating	1	0	1	0	0	2	c
669	Coating	1	0	1	0	0	2	c
670	Coating	1	0	1	0	0	2	c
671	Coating	1	0	1	0	0	2	c
672	Coating	1	0	1	0	0	2	c
673	Coating	1	0	1	0	0	2	c
674	Coating	1	0	1	0	0	2	c

Damage Sample	Type of Damage	S	R	K	F	P	NP	P
675	Coating	1	0	1	0	0	2	c
676	Coating	1	0	1	0	0	2	c
677	Corrosion	1	1	0	0	0	2	d
678	Corrosion	1	1	0	0	0	2	d
679	Corrosion	1	1	0	0	0	2	d
680	Corrosion	1	1	0	0	0	2	d
681	Corrosion	1	1	0	0	0	2	d
682	Corrosion	1	1	0	0	0	2	d
683	Corrosion	1	1	0	0	0	2	d
684	Corrosion	1	1	0	0	0	2	d
685	Corrosion	1	1	0	0	0	2	d
686	Corrosion	1	1	0	0	0	2	d
687	Corrosion	1	1	0	0	0	2	d
688	Corrosion	1	0	0	0	0	1	b
689	Corrosion	1	0	0	0	0	1	b
690	Corrosion	1	1	0	0	0	2	d
691	Corrosion	1	1	0	0	0	2	d
692	Corrosion	1	1	0	0	0	2	d
693	Corrosion	1	1	0	0	0	2	d
694	Corrosion	1	1	0	0	0	2	d
695	Corrosion	1	1	1	0	0	3	d
696	Corrosion	1	1	0	0	0	2	d
697	Corrosion	1	1	0	0	0	2	d
698	Corrosion	1	1	0	0	0	2	d
699	Corrosion	1	1	0	0	0	2	d
700	Corrosion	1	1	0	0	0	2	d
701	Coating	1	1	1	0	0	3	d
702	Coating	1	1	1	0	0	3	d
703	Coating	1	1	1	0	0	3	d
704	Coating	1	1	1	0	0	3	d
705	Coating	1	1	1	0	0	3	d
706	Coating	1	1	1	0	0	3	d
707	Coating	1	1	1	0	0	3	d
708	Coating	1	1	1	0	0	3	d
709	Coating	1	1	1	0	0	3	d
710	Coating	1	1	1	0	0	3	d
711	Coating	1	1	1	0	0	3	d
712	Corrosion	1	1	0	0	0	2	c
713	Corrosion	1	1	0	0	0	2	c
714	Corrosion	1	1	0	0	0	2	c
715	Corrosion	1	1	0	0	0	2	c
716	Coating	1	0	1	0	0	2	e
717	Coating	1	0	1	0	0	2	e
718	Coating	1	0	1	0	0	2	c
719	Coating	1	0	1	0	0	2	c

Damage Sample	Type of Damage	S	R	K	F	P	NP	P
720	Coating	1	0	1	0	0	2	c
721	Coating	1	0	1	0	0	2	c
722	Coating	1	0	1	0	0	2	c
723	Coating	1	0	1	0	0	2	c
724	Corrosion	1	1	0	0	0	2	c
725	Corrosion	1	1	0	0	0	2	c
726	Coating	1	0	1	0	0	2	c
727	Coating	1	0	1	0	0	2	c
728	Coating	1	0	1	0	0	2	c
729	Coating	1	0	1	0	0	2	c
730	Coating	1	0	1	0	0	2	c
731	Coating	1	0	1	0	0	2	c
732	Coating	1	0	1	0	0	2	c
733	Coating	1	0	1	0	0	2	c
734	Coating	1	0	1	0	0	2	c
735	Coating	1	0	1	0	0	2	c
736	Coating	1	0	1	0	0	2	c
737	Coating	1	0	1	0	0	2	c
738	Coating	1	0	1	0	0	2	c
739	Coating	1	0	1	0	0	2	c
740	Coating	1	0	1	0	0	2	e
741	Coating	1	0	1	0	0	2	e
742	Coating	1	0	1	0	0	2	c
743	Coating	1	0	1	0	0	2	c
744	Corrosion	1	1	0	0	0	2	b
745	Corrosion	1	1	0	0	0	2	b
746	Coating	1	0	1	0	0	2	e
747	Coating	1	0	1	0	0	2	e
748	Coating	1	0	1	0	0	2	c
749	Coating	1	0	1	0	0	2	c
750	Corrosion	1	1	0	0	0	2	c
751	Corrosion	1	1	0	0	0	2	c
752	Corrosion	1	1	0	0	0	2	c
753	Corrosion	1	1	0	0	0	2	c
754	Coating	1	0	1	0	0	2	e
755	Coating	1	0	1	0	0	2	e
756	Coating	1	0	1	0	0	2	c
757	Coating	1	0	1	0	0	2	c
758	Coating	1	0	1	0	0	2	c
759	Coating	1	0	1	0	0	2	c
760	Corrosion	1	1	0	0	0	2	c
761	Corrosion	1	1	0	0	0	2	c
762	Coating	1	0	1	0	0	2	e
763	Coating	1	0	1	0	0	2	e
764	Corrosion	1	1	0	0	0	2	c

Damage Sample	Type of Damage	S	R	K	F	P	NP	P
765	Corrosion	1	1	0	0	0	2	c
766	Corrosion	1	1	0	0	0	2	b
767	Corrosion	1	1	0	0	0	2	b
768	Corrosion	1	1	0	0	0	2	b
769	Corrosion	1	1	0	0	0	2	b
770	Corrosion	1	1	0	0	0	2	b
771	Corrosion	1	1	0	0	0	2	b
772	Corrosion	1	1	0	0	0	2	b
773	Corrosion	1	1	0	0	0	2	b
774	Corrosion	1	1	0	0	0	2	b
775	Corrosion	1	1	0	0	0	2	b
776	Corrosion	1	1	0	0	0	2	b
777	Corrosion	1	1	0	0	0	2	b
778	Corrosion	1	1	0	0	0	2	b
779	Corrosion	1	1	0	0	0	2	b
780	Corrosion	1	1	0	0	0	2	b
781	Corrosion	1	1	0	0	0	2	b
782	Corrosion	1	1	0	0	0	2	b
783	Corrosion	1	1	0	0	0	2	b
784	Corrosion	1	1	0	0	0	2	b
785	Corrosion	1	1	0	0	0	2	b
786	Corrosion	1	1	0	0	0	2	d
787	Corrosion	1	1	0	0	0	2	d
788	Corrosion	1	1	0	0	0	2	d
789	Corrosion	1	1	0	0	0	2	d
790	Corrosion	1	1	0	0	0	2	d
791	Corrosion	1	1	0	0	0	2	d
792	Corrosion	1	1	0	0	0	2	b
793	Corrosion	1	1	0	0	0	2	b
794	Corrosion	1	1	0	0	0	2	b
795	Corrosion	1	1	0	0	0	2	b
796	Corrosion	1	1	0	0	0	2	d
797	Corrosion	1	1	0	0	0	2	d
798	Corrosion	1	1	0	0	0	2	d
799	Corrosion	1	1	0	0	0	2	d
800	Corrosion	1	1	0	0	0	2	d
801	Corrosion	1	1	0	0	0	2	d
802	Corrosion	1	1	0	0	0	2	b
803	Corrosion	1	1	0	0	0	2	c
804	Corrosion	1	1	0	0	0	2	c
805	Corrosion	1	0	1	0	0	2	c
806	Corrosion	1	0	1	0	0	2	c
807	Corrosion	1	0	1	0	0	2	c
808	Corrosion	1	0	1	0	0	2	c
809	Corrosion	1	1	0	0	0	2	b

Damage Sample	Type of Damage	S	R	K	F	P	NP	P
810	Corrosion	1	1	0	0	0	2	b
811	Corrosion	1	1	0	0	0	2	b
812	Corrosion	1	1	0	0	0	2	b
813	Corrosion	1	1	0	0	0	2	b
814	Corrosion	1	1	0	0	0	2	b
815	Corrosion	1	1	0	0	0	2	b
816	Corrosion	1	1	0	0	0	2	d
817	Corrosion	1	1	0	0	0	2	b
818	Corrosion	1	1	0	0	0	2	b
819	Coating	1	0	1	0	0	2	d
820	Coating	1	0	1	0	0	2	d
821	Coating	1	0	1	0	0	2	d
822	Coating	1	0	1	0	0	2	e
823	Coating	1	0	1	0	0	2	e
824	Coating	1	0	1	0	0	2	d
825	Coating	1	0	1	0	0	2	d
826	Coating	1	0	1	0	0	2	d
827	Coating	1	0	1	0	0	2	e
828	Coating	1	0	1	0	0	2	e
829	Coating	1	0	1	0	0	2	d
830	Coating	1	0	1	0	0	2	d
831	Coating	1	0	1	0	0	2	e
832	Coating	1	0	1	0	0	2	d
833	Coating	1	0	1	0	0	2	e
834	Coating	1	0	1	0	0	2	e
835	Coating	1	0	1	0	0	2	d
836	Coating	1	0	1	0	0	2	d
837	Coating	1	0	1	0	0	2	d
838	Coating	1	0	1	0	0	2	e
839	Coating	1	0	1	0	0	2	e
840	Coating	1	0	1	0	0	2	e
841	Coating	1	0	1	0	0	2	e
842	Coating	1	0	1	0	0	2	d
843	Coating	1	0	1	0	0	2	e
844	Coating	1	0	1	0	0	2	d
845	Coating	1	0	1	0	0	2	e
846	Coating	1	0	1	0	0	2	e
847	Coating	1	0	1	0	0	2	e
848	Coating	1	0	1	0	0	2	e
849	Coating	1	0	1	0	0	2	d
850	Coating	1	0	1	0	0	2	d
851	Coating	1	0	1	0	0	2	e
852	Coating	1	0	1	0	0	2	d
853	Coating	1	0	1	0	0	2	e
854	Coating	1	0	1	0	0	2	d

Damage Sample	Type of Damage	S	R	K	F	P	NP	P
855	Coating	1	0	1	0	0	2	d
856	Coating	1	0	1	0	0	2	d
857	Coating	1	0	1	0	0	2	d
858	Coating	1	0	1	0	0	2	d
859	Coating	1	0	1	0	0	2	d
860	Coating	1	0	1	0	0	2	d
861	Coating	1	0	1	0	0	2	d
862	Coating	1	0	1	0	0	2	e
863	Coating	1	0	1	0	0	2	e
864	Coating	1	0	1	0	0	2	d
865	Coating	1	0	1	0	0	2	e
866	Coating	1	0	1	0	0	2	e
867	Coating	1	0	1	0	0	2	e
868	Coating	1	0	1	0	0	2	e
869	Coating	1	0	1	0	0	2	e
870	Coating	1	0	1	0	0	2	d
871	Coating	1	0	1	0	0	2	e
872	Coating	1	0	1	0	0	2	e
873	Coating	1	0	1	0	0	2	e
874	Coating	1	0	1	0	0	2	d
875	Coating	1	0	1	0	0	2	d
876	Coating	1	0	1	0	0	2	d
877	Coating	1	0	1	0	0	2	d
878	Coating	1	0	1	0	0	2	d
879	Coating	1	0	1	0	0	2	e
880	Coating	1	0	1	0	0	2	d
881	Coating	1	0	1	0	0	2	d
882	Coating	1	0	1	0	0	2	c
883	Coating	1	1	1	0	0	3	c
884	Coating	1	1	1	0	0	3	c
885	Coating	1	1	1	0	0	3	c
886	Coating	1	1	1	0	0	3	c
887	Coating	1	1	1	0	0	3	c
888	Coating	1	1	1	0	0	3	c
889	Coating	1	1	1	0	0	3	d
890	Coating	1	1	1	0	0	3	d
891	Coating	1	1	1	0	0	3	d
892	Coating	1	1	1	0	0	3	d
893	Coating	1	1	1	0	0	3	d
894	Coating	1	1	1	0	0	3	d
895	Coating	1	1	1	0	0	3	d
896	Coating	1	1	1	0	0	3	d
897	Coating	1	1	1	0	0	3	d
898	Coating	1	1	1	0	0	3	d
899	Coating	1	1	1	0	0	3	d

Damage Sample	Type of Damage	S	R	K	F	P	NP	P
900	Coating	1	1	1	0	0	3	d
901	Coating	1	1	1	0	0	3	d
902	Coating	1	1	1	0	0	3	d
903	Coating	1	1	1	0	0	3	d
904	Coating	1	1	1	0	0	3	d
905	Coating	1	1	1	0	0	3	d
906	Coating	1	1	1	0	0	3	d
907	Coating	1	1	1	0	0	3	d
908	Coating	1	1	1	0	0	3	d
909	Coating	1	1	1	0	0	3	d
910	Coating	1	1	1	0	0	3	d
911	Coating	1	1	1	0	0	3	d
912	Coating	1	1	1	0	0	3	d
913	Coating	1	1	1	0	0	3	d
914	Coating	1	1	1	0	0	3	d
915	Coating	1	1	1	0	0	3	d
916	Coating	1	1	1	0	0	3	d
917	Coating	1	1	1	0	0	3	d
918	Coating	1	1	1	0	0	3	d
919	Coating	1	1	1	0	0	3	d
920	Coating	1	1	1	0	0	3	d
921	Coating	1	1	1	0	0	3	d
922	Coating	1	1	1	0	0	3	d
923	Coating	1	1	1	0	0	3	c
924	Coating	1	1	1	0	0	3	c
925	Coating	1	1	1	0	0	3	c
926	Coating	1	1	1	0	0	3	c
927	Coating	1	1	1	0	0	3	c
928	Coating	1	1	1	0	0	3	c
929	Coating	1	1	1	0	0	3	c
930	Coating	1	1	1	0	0	3	c
931	Coating	1	1	1	0	0	3	c
932	Coating	1	1	1	0	0	3	c
933	Corrosion	1	1	0	0	0	2	b
934	Corrosion	1	1	0	0	0	2	b
935	Coating	1	1	1	0	0	3	e
936	Coating	1	1	1	0	0	3	e
937	Corrosion	1	1	0	0	0	2	b
938	Corrosion	1	1	0	0	0	2	b
939	Corrosion	1	1	0	0	0	2	b
940	Corrosion	1	1	0	0	0	2	b
941	Coating	1	1	1	0	0	3	e
942	Coating	1	1	1	0	0	3	e
943	Coating	1	1	1	0	0	3	e
944	Coating	1	1	1	0	0	3	e

Damage Sample	Type of Damage	S	R	K	F	P	NP	P
945	Corrosion	1	1	0	0	0	2	b
946	Corrosion	1	1	0	0	0	2	b
947	Corrosion	1	1	0	0	0	2	b
948	Corrosion	1	1	0	0	0	2	b
949	Coating	1	1	1	0	0	3	e
950	Coating	1	1	1	0	0	3	e
951	Coating	1	1	1	0	0	3	c
952	Coating	1	1	1	0	0	3	c
953	Corrosion	1	1	0	0	0	2	b
954	Corrosion	1	1	0	0	0	2	b
955	Coating	1	1	1	0	0	3	e
956	Corrosion	1	1	0	0	0	2	b
957	Corrosion	1	1	0	0	0	2	b
958	Coating	1	1	1	0	0	3	e
959	Coating	1	1	1	0	0	3	e
960	Corrosion	1	1	0	0	0	2	b
961	Corrosion	1	1	0	0	0	2	b
962	Coating	1	1	1	0	0	3	e
963	Coating	1	1	1	0	0	3	e
964	Corrosion	1	1	0	0	0	2	b
965	Corrosion	1	1	0	0	0	2	b
966	Coating	1	1	1	0	0	3	e
967	Coating	1	1	1	0	0	3	e
968	Corrosion	1	1	0	0	0	2	b
969	Corrosion	1	1	0	0	0	2	b
970	Coating	1	1	1	0	0	3	e
971	Coating	1	1	1	0	0	3	e
972	Corrosion	1	1	0	0	0	2	b
973	Corrosion	1	1	0	0	0	2	b
974	Coating	1	1	1	0	0	3	e
975	Coating	1	1	1	0	0	3	e
976	Corrosion	1	1	0	0	0	2	b
977	Corrosion	1	1	0	0	0	2	b
978	Coating	1	1	1	0	0	3	e
979	Coating	1	1	1	0	0	3	e
980	Corrosion	1	1	0	0	0	2	b
981	Corrosion	1	1	0	0	0	2	b
982	Coating	1	1	1	0	0	3	e
983	Coating	1	1	1	0	0	3	e
984	Corrosion	1	1	0	0	0	2	b
985	Corrosion	1	1	0	0	0	2	b
986	Coating	1	1	1	0	0	3	e
987	Coating	1	1	1	0	0	3	e
988	Corrosion	1	1	0	0	0	2	b
989	Corrosion	1	1	0	0	0	2	b

Damage Sample	Type of Damage	S	R	K	F	P	NP	P
990	Coating	1	1	1	0	0	3	e
991	Coating	1	1	1	0	0	3	e
992	Corrosion	1	1	0	0	0	2	b
993	Corrosion	1	1	0	0	0	2	b
994	Coating	1	1	1	0	0	3	e
995	Coating	1	1	1	0	0	3	e
996	Corrosion	1	1	0	0	0	2	b
997	Corrosion	1	1	0	0	0	2	b
998	Coating	1	1	1	0	0	3	e
999	Coating	1	1	1	0	0	3	e
1000	Corrosion	1	1	0	0	0	2	b
1001	Corrosion	1	1	0	0	0	2	b
1002	Coating	1	1	1	0	0	3	e
1003	Coating	1	1	1	0	0	3	e
1004	Corrosion	1	1	0	0	0	2	b
1005	Corrosion	1	1	0	0	0	2	b
1006	Coating	1	1	1	0	0	3	e
1007	Coating	1	1	1	0	0	3	e
1008	Corrosion	1	1	0	0	0	2	b
1009	Corrosion	1	1	0	0	0	2	b
1010	Coating	1	1	1	0	0	3	e
1011	Coating	1	1	1	0	0	3	e
1012	Corrosion	1	1	0	0	0	2	b
1013	Corrosion	1	1	0	0	0	2	b
1014	Coating	1	1	1	0	0	3	e
1015	Coating	1	1	1	0	0	3	e
1016	Corrosion	1	1	0	0	0	2	b
1017	Corrosion	1	1	0	0	0	2	b
1018	Coating	1	1	1	0	0	3	e
1019	Coating	1	1	1	0	0	3	e
1020	Corrosion	1	1	0	0	0	2	b
1021	Corrosion	1	1	0	0	0	2	b
1022	Coating	1	1	1	0	0	3	e
1023	Coating	1	1	1	0	0	3	e
1024	Corrosion	1	1	0	0	0	2	b
1025	Corrosion	1	1	0	0	0	2	b
1026	Coating	1	1	1	0	0	3	e
1027	Coating	1	1	1	0	0	3	e
1028	Corrosion	1	1	0	0	0	2	b
1029	Corrosion	1	1	0	0	0	2	b
1030	Coating	1	1	1	0	0	3	e
1031	Coating	1	1	1	0	0	3	e
1032	Corrosion	1	1	0	0	0	2	b
1033	Corrosion	1	1	0	0	0	2	b
1034	Coating	1	1	1	0	0	3	e

Damage Sample	Type of Damage	S	R	K	F	P	NP	P
1035	Coating	1	1	1	0	0	3	e
1036	Corrosion	1	1	0	0	0	2	b
1037	Corrosion	1	1	0	0	0	2	b
1038	Coating	1	1	1	0	0	3	e
1039	Coating	1	1	1	0	0	3	e
1040	Corrosion	1	1	0	0	0	2	b
1041	Corrosion	1	1	0	0	0	2	b
1042	Coating	1	1	1	0	0	3	e
1043	Coating	1	1	1	0	0	3	e
1044	Corrosion	1	1	0	0	0	2	b
1045	Corrosion	1	1	0	0	0	2	b
1046	Coating	1	1	1	0	0	3	e
1047	Coating	1	1	1	0	0	3	e
1048	Corrosion	1	1	0	0	0	2	b
1049	Corrosion	1	1	0	0	0	2	b
1050	Coating	1	1	1	0	0	3	e
1051	Coating	1	1	1	0	0	3	e
1052	Corrosion	1	1	0	0	0	2	b
1053	Corrosion	1	1	0	0	0	2	b
1054	Coating	1	1	1	0	0	3	e
1055	Coating	1	1	1	0	0	3	e
1056	Corrosion	1	1	0	0	0	2	b
1057	Corrosion	1	1	0	0	0	2	b
1058	Coating	1	1	1	0	0	3	e
1059	Coating	1	1	1	0	0	3	e
1060	Corrosion	1	1	0	0	0	2	b
1061	Corrosion	1	1	0	0	0	2	b
1062	Coating	1	1	1	0	0	3	e
1063	Coating	1	1	1	0	0	3	e
1064	Corrosion	1	1	0	0	0	2	b
1065	Corrosion	1	1	0	0	0	2	b
1066	Coating	1	1	1	0	0	3	e
1067	Coating	1	1	1	0	0	3	e
1068	Corrosion	1	1	0	0	0	2	b
1069	Corrosion	1	1	0	0	0	2	b
1070	Coating	1	1	1	0	0	3	e
1071	Coating	1	1	1	0	0	3	e
1072	Corrosion	1	1	0	0	0	2	b
1073	Corrosion	1	1	0	0	0	2	b
1074	Coating	1	1	1	0	0	3	e
1075	Coating	1	1	1	0	0	3	e
1076	Corrosion	1	1	0	0	0	2	b
1077	Corrosion	1	1	0	0	0	2	b
1078	Coating	1	1	1	0	0	3	e
1079	Coating	1	1	1	0	0	3	e

Damage Sample	Type of Damage	S	R	K	F	P	NP	P
1080	Corrosion	1	1	0	0	0	2	b
1081	Corrosion	1	1	0	0	0	2	b
1082	Coating	1	1	1	0	0	3	e
1083	Coating	1	1	1	0	0	3	e
1084	Corrosion	1	1	0	0	0	2	b
1085	Corrosion	1	1	0	0	0	2	b
1086	Coating	1	0	1	0	0	2	e
1087	Coating	1	0	1	0	0	2	e
1088	Corrosion	1	1	0	0	0	2	b
1089	Corrosion	1	1	0	0	0	2	b
1090	Coating	1	0	1	0	0	2	e
1091	Coating	1	0	1	0	0	2	e
1092	Corrosion	1	1	0	0	0	2	b
1093	Corrosion	1	1	0	0	0	2	b
1094	Coating	1	1	1	0	0	3	e
1095	Coating	1	1	1	0	0	3	e
1096	Corrosion	1	1	0	0	0	2	b
1097	Corrosion	1	1	0	0	0	2	b
1098	Coating	1	0	1	0	0	2	e
1099	Coating	1	0	1	0	0	2	e
1100	Corrosion	1	1	0	0	0	2	b
1101	Coating	1	0	1	0	0	2	e
1102	Corrosion	1	1	0	0	0	2	b
1103	Corrosion	1	1	0	0	0	2	b
1104	Coating	1	1	1	0	0	3	e
1105	Coating	1	1	1	0	0	3	e
1106	Corrosion	1	1	0	0	0	2	b
1107	Corrosion	1	1	0	0	0	2	b
1108	Coating	1	1	1	0	0	3	e
1109	Coating	1	1	1	0	0	3	e
1110	Corrosion	1	1	0	0	0	2	b
1111	Corrosion	1	1	0	0	0	2	b
1112	Coating	1	1	1	0	0	3	e
1113	Coating	1	1	1	0	0	3	e
1114	Corrosion	1	1	0	0	0	2	b
1115	Corrosion	1	1	0	0	0	2	b
1116	Coating	1	1	1	0	0	3	e
1117	Coating	1	1	1	0	0	3	e
1118	Corrosion	1	1	0	0	0	2	b
1119	Corrosion	1	1	0	0	0	2	b
1120	Coating	1	1	1	0	0	3	e
1121	Coating	1	1	1	0	0	3	e
1122	Corrosion	1	1	0	0	0	2	b
1123	Corrosion	1	1	0	0	0	2	b
1124	Coating	1	1	1	0	0	3	e

Damage Sample	Type of Damage	S	R	K	F	P	NP	P
1125	Coating	1	1	1	0	0	3	e
1126	Corrosion	1	1	0	0	0	2	b
1127	Corrosion	1	1	0	0	0	2	b
1128	Coating	1	1	1	0	0	3	e
1129	Coating	1	1	1	0	0	3	e
1130	Corrosion	1	1	0	0	0	2	b
1131	Corrosion	1	1	0	0	0	2	b
1132	Coating	1	1	1	0	0	3	e
1133	Coating	1	1	1	0	0	3	e
1134	Corrosion	1	1	0	0	0	2	b
1135	Corrosion	1	1	0	0	0	2	b
1136	Coating	1	1	1	0	0	3	e
1137	Coating	1	1	1	0	0	3	e
1138	Corrosion	1	1	0	0	0	2	b
1139	Corrosion	1	1	0	0	0	2	b
1140	Coating	1	1	1	0	0	3	e
1141	Coating	1	1	1	0	0	3	e
1142	Corrosion	1	1	1	0	0	3	d
1143	Corrosion	1	1	1	0	0	3	d
1144	Corrosion	1	1	1	0	0	3	d
1145	Corrosion	1	1	1	0	0	3	c
1146	Corrosion	1	1	1	0	0	3	c
1147	Corrosion	1	1	1	0	0	3	d
1148	Corrosion	1	1	1	0	0	3	d
1149	Corrosion	1	1	1	0	0	3	d
1150	Corrosion	1	1	1	0	0	3	d
1151	Coating	1	1	1	0	0	3	e
1152	Corrosion	1	1	1	0	0	3	d
1153	Corrosion	1	1	1	0	0	3	d

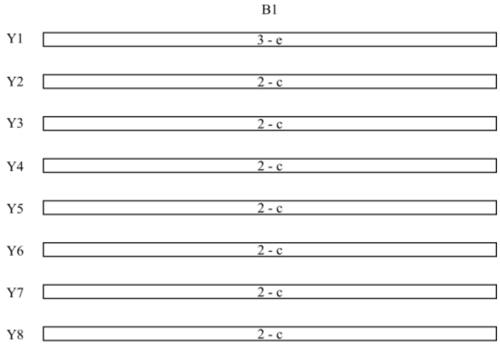
Appendix-D

Visual Inspection Results for 30 Bridges on the National Roads of East Java Province, Indonesia

1. Bridge 1C

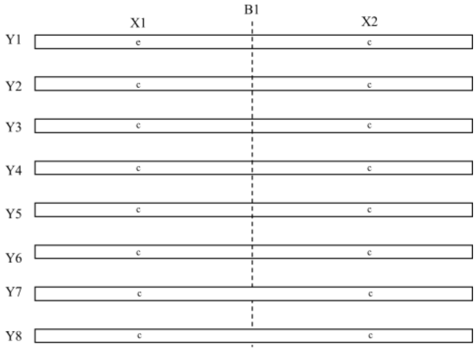
Image

Non-Physical (One Segment)



	B1
Y1	3 - e
Y2	2 - c
Y3	2 - c
Y4	2 - c
Y5	2 - c
Y6	2 - c
Y7	2 - c
Y8	2 - c

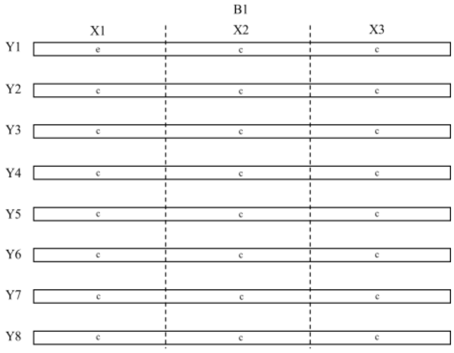
Physical (Two Segment)



B1

	X1	X2
Y1	e	c
Y2	c	c
Y3	c	c
Y4	c	c
Y5	c	c
Y6	c	c
Y7	c	c
Y8	c	c

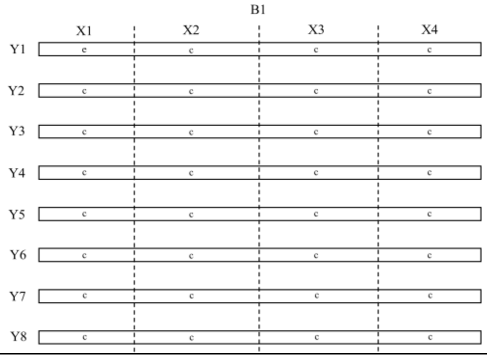
Physical (Three Segment)



B1

	X1	X2	X3
Y1	e	c	c
Y2	c	c	c
Y3	c	c	c
Y4	c	c	c
Y5	c	c	c
Y6	c	c	c
Y7	c	c	c
Y8	c	c	c

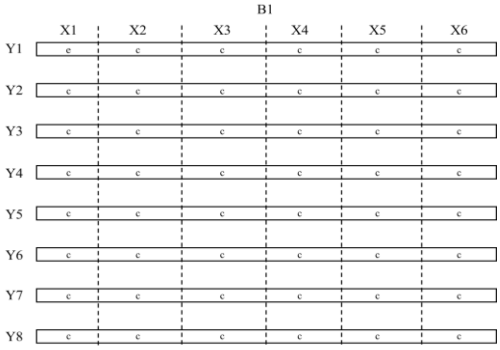
Physical (Four Segment)



B1

	X1	X2	X3	X4
Y1	e	c	c	c
Y2	c	c	c	c
Y3	c	c	c	c
Y4	c	c	c	c
Y5	c	c	c	c
Y6	c	c	c	c
Y7	c	c	c	c
Y8	c	c	c	c

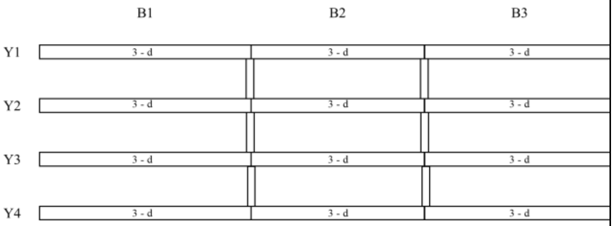
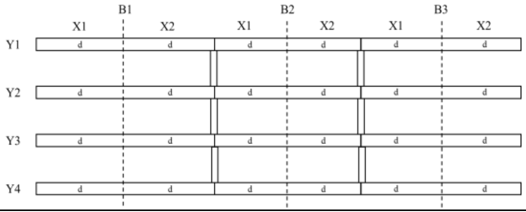
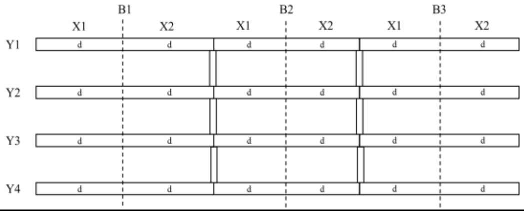
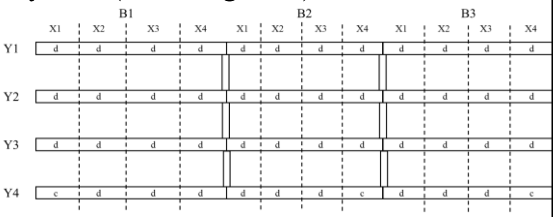
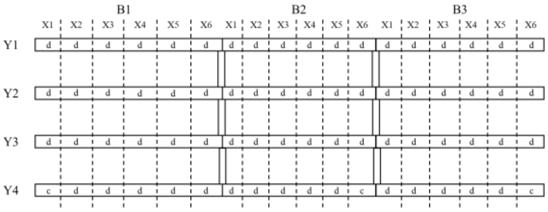
Physical (Six Segment)



B1

	X1	X2	X3	X4	X5	X6
Y1	e	c	c	c	c	c
Y2	c	c	c	c	c	c
Y3	c	c	c	c	c	c
Y4	c	c	c	c	c	c
Y5	c	c	c	c	c	c
Y6	c	c	c	c	c	c
Y7	c	c	c	c	c	c
Y8	c	c	c	c	c	c

2. Bridge 2C

Image 	Non-Physical (One Segment) 
Physical (Two Segment) 	Physical (Three Segment) 
Physical (Four Segment) 	Physical (Six Segment) 

3. Bridge 3C

Image

Non-Physical (One Segment)

	B1
Y1	3 - e
Y2	3 - e
Y3	2 - c
Y4	2 - c
Y5	2 - c
Y6	3 - e
Y7	3 - e
Y8	3 - e

Physical (Two Segment)

B1

	X1	X2
Y1	e	e
Y2	e	e
Y3	c	c
Y4	c	c
Y5	c	c
Y6	e	e
Y7	e	e
Y8	e	e

Physical (Three Segment)

B1

	X1	X2	X3
Y1	e	e	e
Y2	e	e	e
Y3	c	c	c
Y4	c	c	c
Y5	c	c	c
Y6	e	e	e
Y7	e	e	e
Y8	e	e	e

Physical (Four Segment)

B1

	X1	X2	X3	X4
Y1	e	e	e	e
Y2	e	e	e	e
Y3	c	c	c	c
Y4	c	c	c	c
Y5	c	c	c	c
Y6	e	e	e	e
Y7	e	e	e	e
Y8	e	e	e	e

Physical (Six Segment)

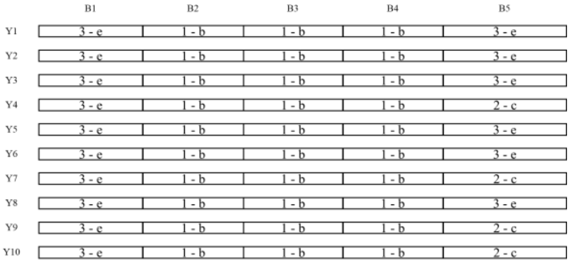
B1

	X1	X2	X3	X4	X5	X6
Y1	e	e	e	e	e	e
Y2	e	e	e	e	e	e
Y3	c	c	c	c	c	c
Y4	c	c	c	c	c	c
Y5	c	c	c	c	c	c
Y6	e	e	e	e	e	e
Y7	e	e	e	e	e	e
Y8	e	e	e	e	e	e

4. Bridge 4C

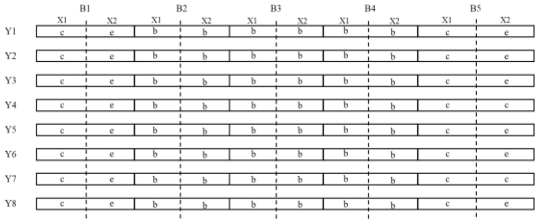
Image

Non-Physical (One Segment)



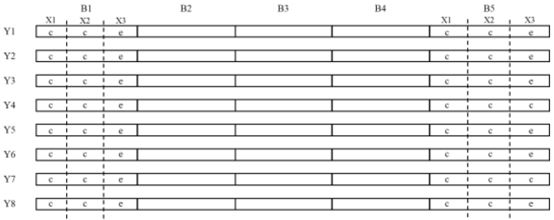
	B1	B2	B3	B4	B5
Y1	3 - e	1 - b	1 - b	1 - b	3 - e
Y2	3 - e	1 - b	1 - b	1 - b	3 - e
Y3	3 - e	1 - b	1 - b	1 - b	3 - e
Y4	3 - e	1 - b	1 - b	1 - b	2 - c
Y5	3 - e	1 - b	1 - b	1 - b	3 - e
Y6	3 - e	1 - b	1 - b	1 - b	3 - e
Y7	3 - e	1 - b	1 - b	1 - b	2 - c
Y8	3 - e	1 - b	1 - b	1 - b	3 - e
Y9	3 - e	1 - b	1 - b	1 - b	2 - c
Y10	3 - e	1 - b	1 - b	1 - b	2 - c

Physical (Two Segment)



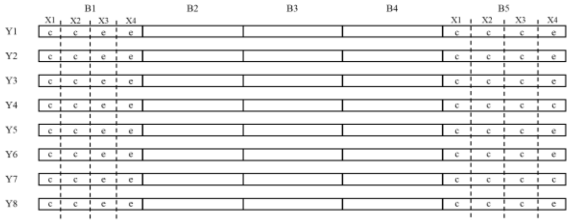
	B1		B2		B3		B4		B5	
	X1	X2	X1	X2	X1	X2	X1	X2	X1	X2
Y1	c	e	b	b	b	b	b	b	c	e
Y2	c	e	b	b	b	b	b	b	c	e
Y3	c	e	b	b	b	b	b	b	c	e
Y4	c	e	b	b	b	b	b	b	c	c
Y5	c	e	b	b	b	b	b	b	c	e
Y6	c	e	b	b	b	b	b	b	c	e
Y7	c	e	b	b	b	b	b	b	c	c
Y8	c	e	b	b	b	b	b	b	c	e
Y9	c	e	b	b	b	b	b	b	c	c
Y10	c	e	b	b	b	b	b	b	c	c

Physical (Three Segment)



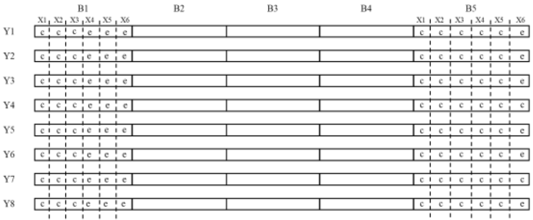
	B1			B2	B3	B4	B5		
	X1	X2	X3				X1	X2	X3
Y1	c	c	e				c	c	e
Y2	c	c	e				c	c	e
Y3	c	c	e				c	c	e
Y4	c	c	e				c	c	c
Y5	c	c	e				c	c	e
Y6	c	c	e				c	c	e
Y7	c	c	e				c	c	c
Y8	c	c	e				c	c	e
Y9	c	c	e				c	c	c
Y10	c	c	e				c	c	c

Physical (Four Segment)



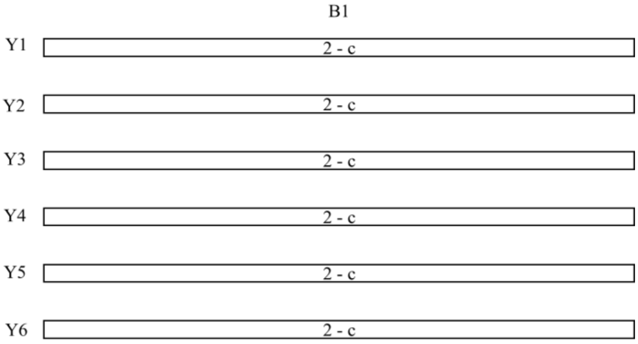
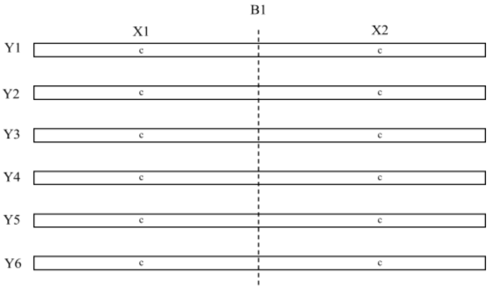
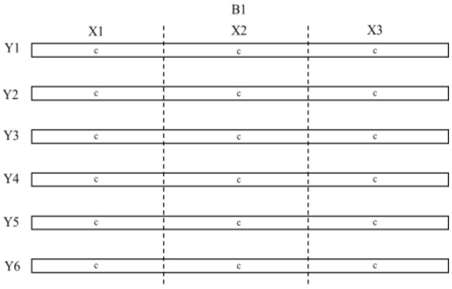
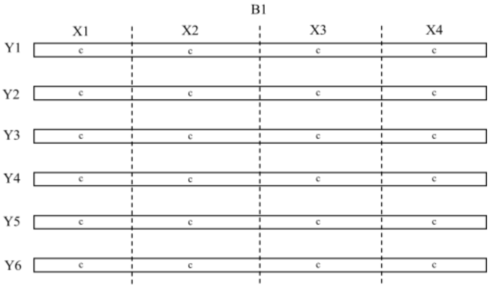
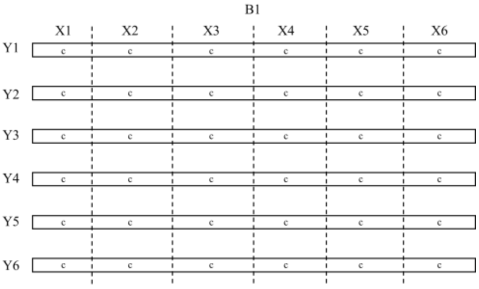
	B1				B2	B3	B4	B5			
	X1	X2	X3	X4				X1	X2	X3	X4
Y1	c	c	e	e				c	c	c	e
Y2	c	c	e	e				c	c	c	e
Y3	c	c	e	e				c	c	c	e
Y4	c	c	e	e				c	c	c	c
Y5	c	c	e	e				c	c	c	e
Y6	c	c	e	e				c	c	c	e
Y7	c	c	e	e				c	c	c	c
Y8	c	c	e	e				c	c	c	e
Y9	c	c	e	e				c	c	c	c
Y10	c	c	e	e				c	c	c	c

Physical (Six Segment)



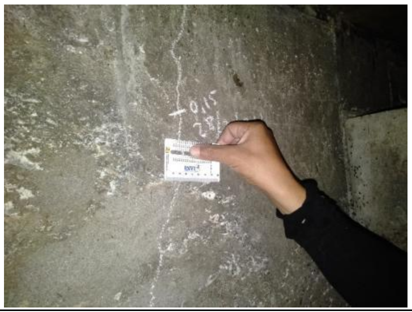
	B1						B2	B3	B4	B5					
	X1	X2	X3	X4	X5	X6				X1	X2	X3	X4	X5	X6
Y1	c	c	c	e	e	e				c	c	c	c	c	e
Y2	c	c	c	e	e	e				c	c	c	c	c	e
Y3	c	c	c	e	e	e				c	c	c	c	c	e
Y4	c	c	c	e	e	e				c	c	c	c	c	c
Y5	c	c	c	e	e	e				c	c	c	c	c	e
Y6	c	c	c	e	e	e				c	c	c	c	c	e
Y7	c	c	c	e	e	e				c	c	c	c	c	c
Y8	c	c	c	e	e	e				c	c	c	c	c	e
Y9	c	c	c	e	e	e				c	c	c	c	c	c
Y10	c	c	c	e	e	e				c	c	c	c	c	c

5. Bridge 5C

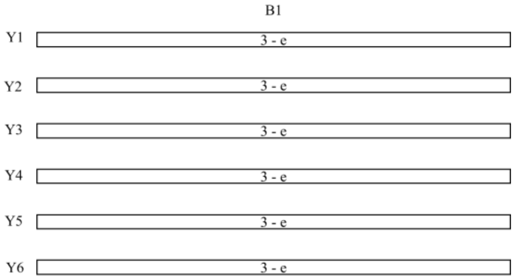
Image	Non-Physical (One Segment)
	
Physical (Two Segment)	**Physical (Three Segment)**
	
Physical (Four Segment)	**Physical (Six Segment)**
	

6. Bridge 6C

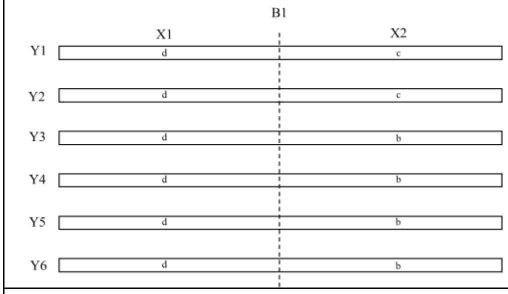
Image



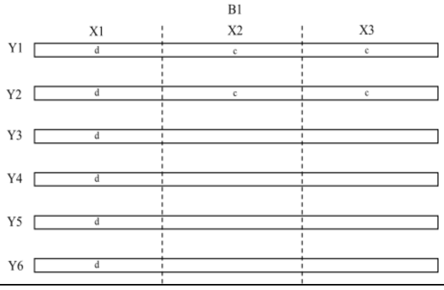
Non-Physical (One Segment)



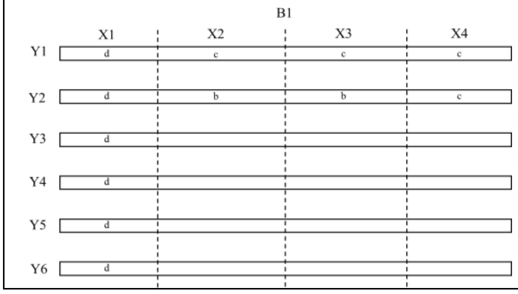
Physical (Two Segment)



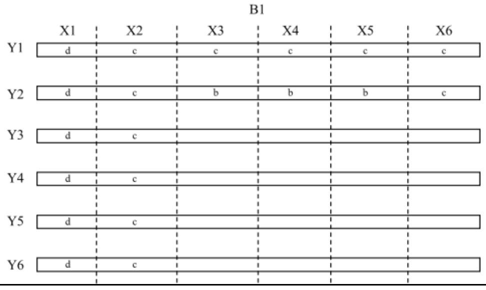
Physical (Three Segment)



Physical (Four Segment)



Physical (Six Segment)



7. Bridge 7C

Image

Non-Physical (One Segment)

	B1
Y1	3 - e
Y2	1 - b
Y3	2 - c
Y4	1 - b
Y5	1 - b
Y6	2 - c
Y7	2 - c
Y8	2 - c
Y9	1 - b
Y10	1 - b
Y11	1 - b
Y12	1 - b
Y13	2 - c
Y14	1 - b
Y15	1 - b
Y16	2 - c

Physical (Two Segment)

	B1	
	X1	X2
Y1	e	e
Y2	b	b
Y3	c	c
Y4	b	b
Y5	b	b
Y6	c	b
Y7	c	c
Y8	c	b
Y9	b	b
Y10	b	b
Y11	b	b
Y12	b	b
Y13	c	b
Y14	b	b
Y15	b	b
Y16	c	b

Physical (Three Segment)

	X1	X2	X3
Y1	e	e	e
Y2	b	b	b
Y3	c	b	c
Y4	b	b	b
Y5	b	b	b
Y6	c	b	b
Y7	c	b	c
Y8	c	b	b
Y9	b	b	b
Y10	b	b	b
Y11	b	b	b
Y12	b	b	b
Y13	c	b	b
Y14	b	b	b
Y15	b	b	b
Y16	c	b	b

Physical (Four Segment)

	B1			
	X1	X2	X3	X4
Y1	e	e	e	e
Y2	b	b	b	b
Y3	c	b	b	c
Y4	b	b	b	b
Y5	b	b	b	b
Y6	c	b	b	b
Y7	c	b	b	c
Y8	c	b	b	b
Y9	b	b	b	b
Y10	b	b	b	b
Y11	b	b	b	b
Y12	b	b	b	b
Y13	c	b	b	b
Y14	b	b	b	b
Y15	b	b	b	b
Y16	c	b	b	b

Physical (Six Segment)

	B1					
	X1	X2	X3	X4	X5	X6
Y1	e	e	e	e	e	e
Y2	b	b	b	b	b	b
Y3	c	b	b	b	b	c
Y4	b	b	b	b	b	b
Y5	b	b	b	b	b	b
Y6	c	b	b	b	b	b
Y7	c	b	b	b	b	c
Y8	c	b	b	b	b	b
Y9	b	b	b	b	b	b
Y10	b	b	b	b	b	b
Y11	b	b	b	b	b	b
Y12	b	b	b	b	b	b
Y13	c	b	b	b	b	b
Y14	b	b	b	b	b	b
Y15	b	b	b	b	b	b
Y16	c	c	b	b	b	b

8. Bridge 8C

Image

Non-Physical (One Segment)

	B1
Y1	2 - c
Y2	1 - b
Y3	2 - c
Y4	1 - b
Y5	2 - c
Y6	2 - c
Y7	1 - b
Y8	1 - b
Y9	1 - b
Y10	2 - c
Y11	2 - c
Y12	2 - c
Y13	2 - c
Y14	2 - c
Y15	2 - c
Y16	2 - c
Y17	3 - e

Physical (Two Segment)

	B1	
	X1	X2
Y1	b	c
Y2	b	b
Y3	b	c
Y4	b	b
Y5	c	b
Y6	b	c
Y7	b	b
Y8	b	b
Y9	b	b
Y10	c	b
Y11	b	c
Y12	c	c
Y13	c	c
Y14	c	c
Y15	c	b
Y16	c	c
Y17	e	e

Physical (Three Segment)

	B1		
	X1	X2	X3
Y1	b	b	c
Y2	b	b	b
Y3	b	b	c
Y4	b	b	b
Y5	c	b	b
Y6	b	b	c
Y7	b	b	b
Y8	b	b	b
Y9	b	b	b
Y10	c	b	b
Y11	b	b	c
Y12	c	b	c
Y13	c	b	c
Y14	c	b	c
Y15	c	b	b
Y16	c	b	c
Y17	e	c	e

Physical (Four Segment)

	B1			
	X1	X2	X3	X4
Y1	b	b	b	c
Y2	b	b	b	b
Y3	b	b	b	c
Y4	b	b	b	b
Y5	c	b	b	b
Y6	b	b	b	c
Y7	b	b	b	b
Y8	b	b	b	b
Y9	b	b	b	b
Y10	c	b	b	b
Y11	b	b	b	c
Y12	c	b	b	c
Y13	c	b	b	c
Y14	c	b	b	c
Y15	c	b	b	b
Y16	c	b	b	c
Y17	e	c	c	e

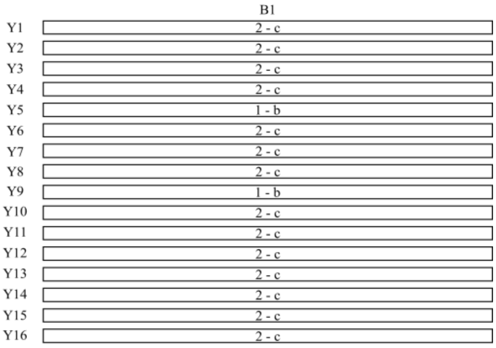
Physical (Six Segment)

	B1					
	X1	X2	X3	X4	X5	X6
Y1	b	b	b	b	b	c
Y2	b	b	b	b	b	b
Y3	b	b	b	b	b	c
Y4	b	b	b	b	b	b
Y5	c	b	b	b	b	b
Y6	b	b	b	b	b	c
Y7	b	b	b	b	b	b
Y8	b	b	b	b	b	b
Y9	b	b	b	b	b	b
Y10	c	b	b	b	b	b
Y11	b	b	b	b	b	c
Y12	c	b	b	b	b	c
Y13	c	b	b	b	b	c
Y14	c	b	b	b	b	c
Y15	c	b	b	b	b	b
Y16	c	b	b	b	b	c
Y17	e	c	c	c	c	e

9. Bridge 9C

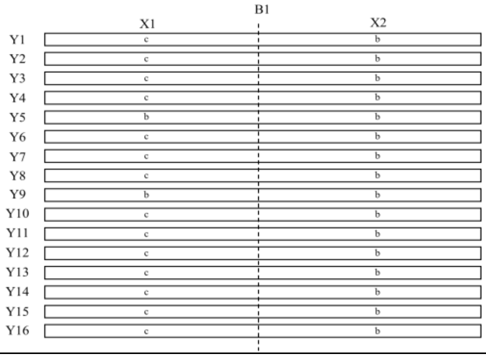
Image

Non-Physical (One Segment)



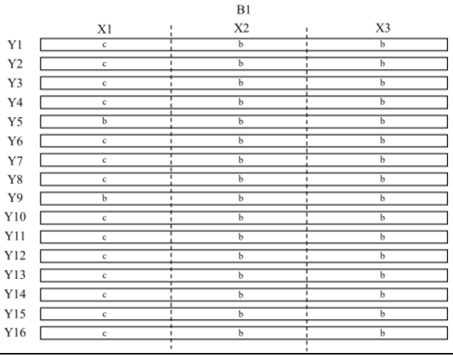
	B1
Y1	2 - c
Y2	2 - c
Y3	2 - c
Y4	2 - c
Y5	1 - b
Y6	2 - c
Y7	2 - c
Y8	2 - c
Y9	1 - b
Y10	2 - c
Y11	2 - c
Y12	2 - c
Y13	2 - c
Y14	2 - c
Y15	2 - c
Y16	2 - c

Physical (Two Segment)



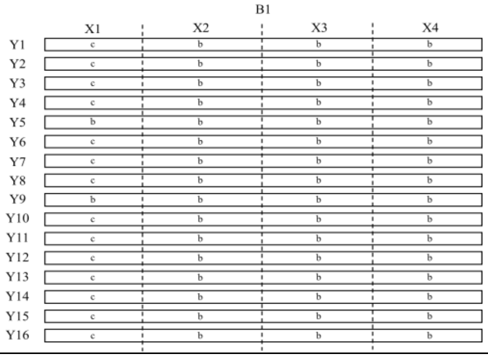
	B1	
	X1	X2
Y1	c	b
Y2	c	b
Y3	c	b
Y4	c	b
Y5	b	b
Y6	c	b
Y7	c	b
Y8	c	b
Y9	b	b
Y10	c	b
Y11	c	b
Y12	c	b
Y13	c	b
Y14	c	b
Y15	c	b
Y16	c	b

Physical (Three Segment)



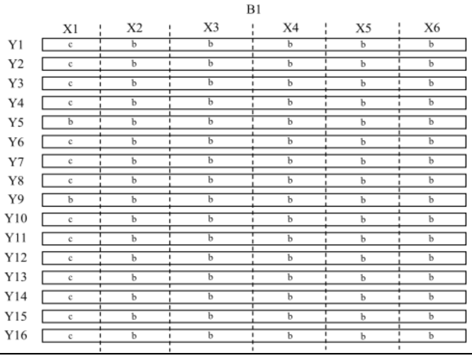
	B1		
	X1	X2	X3
Y1	c	b	b
Y2	c	b	b
Y3	c	b	b
Y4	c	b	b
Y5	b	b	b
Y6	c	b	b
Y7	c	b	b
Y8	c	b	b
Y9	b	b	b
Y10	c	b	b
Y11	c	b	b
Y12	c	b	b
Y13	c	b	b
Y14	c	b	b
Y15	c	b	b
Y16	c	b	b

Physical (Four Segment)



	B1			
	X1	X2	X3	X4
Y1	c	b	b	b
Y2	c	b	b	b
Y3	c	b	b	b
Y4	c	b	b	b
Y5	b	b	b	b
Y6	c	b	b	b
Y7	c	b	b	b
Y8	c	b	b	b
Y9	b	b	b	b
Y10	c	b	b	b
Y11	c	b	b	b
Y12	c	b	b	b
Y13	c	b	b	b
Y14	c	b	b	b
Y15	c	b	b	b
Y16	c	b	b	b

Physical (Six Segment)



	B1					
	X1	X2	X3	X4	X5	X6
Y1	c	b	b	b	b	b
Y2	c	b	b	b	b	b
Y3	c	b	b	b	b	b
Y4	c	b	b	b	b	b
Y5	b	b	b	b	b	b
Y6	c	b	b	b	b	b
Y7	c	b	b	b	b	b
Y8	c	b	b	b	b	b
Y9	b	b	b	b	b	b
Y10	c	b	b	b	b	b
Y11	c	b	b	b	b	b
Y12	c	b	b	b	b	b
Y13	c	b	b	b	b	b
Y14	c	b	b	b	b	b
Y15	c	b	b	b	b	b
Y16	c	b	b	b	b	b

10. Bridge 10C

Image

Non-Physical (One Segment)

	B1
Y1	3 - e
Y2	3 - e
Y3	3 - e
Y4	0 - a
Y5	0 - a
Y6	0 - a
Y7	0 - a
Y8	2 - c
Y9	2 - c
Y10	2 - c
Y11	2 - c
Y12	3 - e
Y13	2 - c
Y14	3 - e
Y15	3 - e
Y16	3 - e
Y17	3 - e

Physical (Two Segment)

	B1	
	X1	X2
Y1	e	e
Y2	e	e
Y3	e	a
Y4	a	a
Y5	a	a
Y6	a	a
Y7	a	a
Y8	a	e
Y9	a	e
Y10	a	e
Y11	a	e
Y12	a	e
Y13	b	e
Y14	b	e
Y15	e	e
Y16	b	e
Y17	b	e

Physical (Three Segment)

	B1		
	X1	X2	X3
Y1	e	e	e
Y2	e	a	e
Y3	e	a	a
Y4	a	a	a
Y5	a	a	a
Y6	a	a	a
Y7	a	a	a
Y8	a	b	e
Y9	a	a	e
Y10	a	a	e
Y11	a	a	e
Y12	a	e	e
Y13	a	e	a
Y14	a	e	e
Y15	a	e	e
Y16	a	e	e
Y17	a	e	e

Physical (Four Segment)

	B1			
	X1	X2	X3	X4
Y1	e	e	e	e
Y2	e	a	a	e
Y3	e	a	a	a
Y4	a	a	a	a
Y5	a	a	a	a
Y6	a	a	a	a
Y7	a	a	a	a
Y8	a	a	a	b
Y9	a	a	b	e
Y10	a	a	a	e
Y11	a	a	a	e
Y12	a	a	e	e
Y13	a	a	e	a
Y14	a	b	e	e
Y15	a	b	e	a
Y16	a	b	e	e
Y17	a	b	e	e

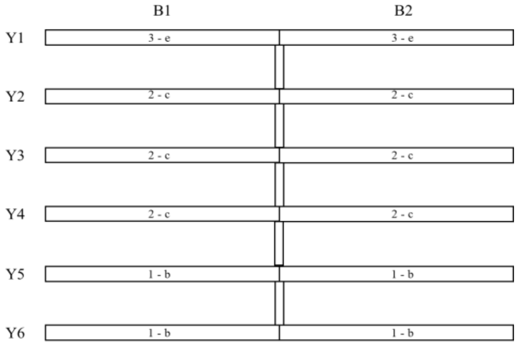
Physical (Six Segment)

	B1					
	X1	X2	X3	X4	X5	X6
Y1	e	e	e	e	e	e
Y2	e	e	a	a	e	e
Y3	e	e	a	a	a	a
Y4	a	a	a	a	a	a
Y5	a	a	a	a	a	a
Y6	a	a	a	a	a	a
Y7	a	a	a	a	a	a
Y8	a	a	a	a	e	e
Y9	a	a	a	a	e	e
Y10	a	a	a	a	e	e
Y11	a	a	a	a	e	e
Y12	a	a	e	e	e	a
Y13	a	a	b	e	a	a
Y14	a	a	e	e	e	a
Y15	a	a	e	e	e	a
Y16	a	a	b	e	e	b
Y17	a	a	b	e	e	e

11. Bridge 11C

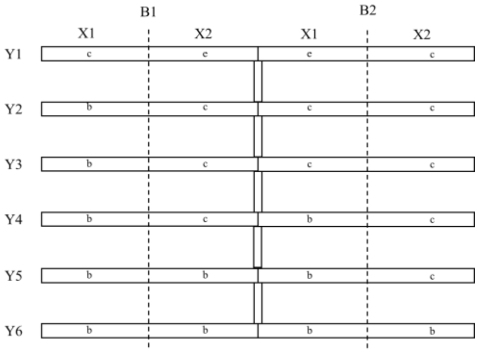
Image

Non-Physical (One Segment)



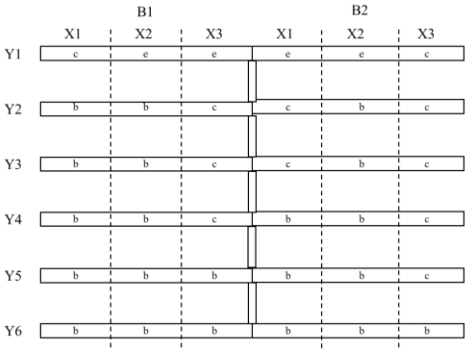
	B1	B2
Y1	3 - e	3 - e
Y2	2 - c	2 - c
Y3	2 - c	2 - c
Y4	2 - c	2 - c
Y5	1 - b	1 - b
Y6	1 - b	1 - b

Physical (Two Segment)



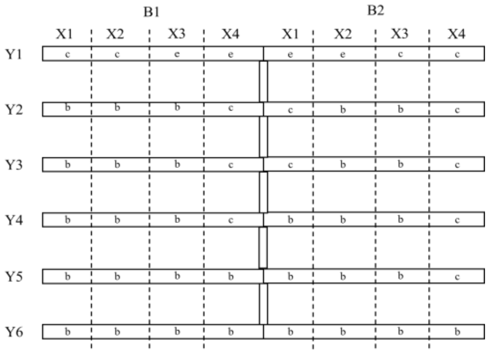
	B1		B2	
	X1	X2	X1	X2
Y1	c	e	e	c
Y2	b	c	c	c
Y3	b	c	c	c
Y4	b	c	b	c
Y5	b	b	b	c
Y6	b	b	b	b

Physical (Three Segment)



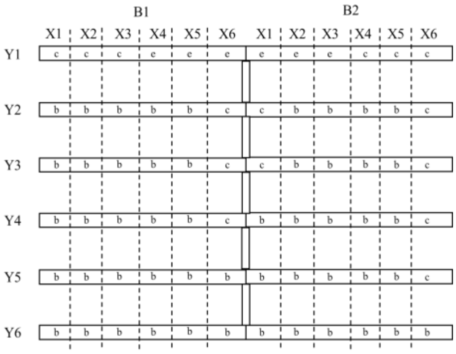
	B1			B2		
	X1	X2	X3	X1	X2	X3
Y1	c	e	e	e	e	c
Y2	b	b	c	c	b	c
Y3	b	b	c	c	b	c
Y4	b	b	c	b	b	c
Y5	b	b	b	b	b	c
Y6	b	b	b	b	b	b

Physical (Four Segment)



	B1				B2			
	X1	X2	X3	X4	X1	X2	X3	X4
Y1	c	c	e	e	e	e	c	c
Y2	b	b	b	c	c	b	b	c
Y3	b	b	b	c	c	b	b	c
Y4	b	b	b	c	b	b	b	c
Y5	b	b	b	b	b	b	b	c
Y6	b	b	b	b	b	b	b	b

Physical (Six Segment)

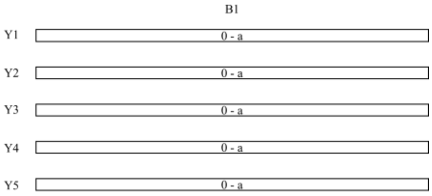


	B1						B2					
	X1	X2	X3	X4	X5	X6	X1	X2	X3	X4	X5	X6
Y1	c	c	c	e	e	e	e	e	e	c	c	c
Y2	b	b	b	b	b	c	c	b	b	b	b	c
Y3	b	b	b	b	b	c	c	b	b	b	b	c
Y4	b	b	b	b	b	c	b	b	b	b	b	c
Y5	b	b	b	b	b	b	b	b	b	b	b	c
Y6	b	b	b	b	b	b	b	b	b	b	b	b

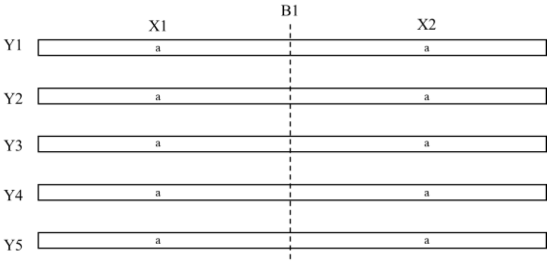
12. Bridge 12C

Image

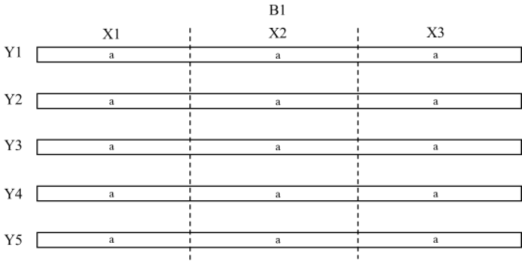
Non-Physical (One Segment)



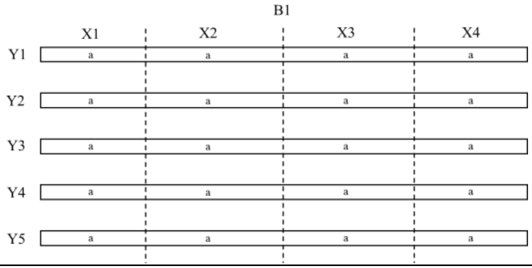
Physical (Two Segment)



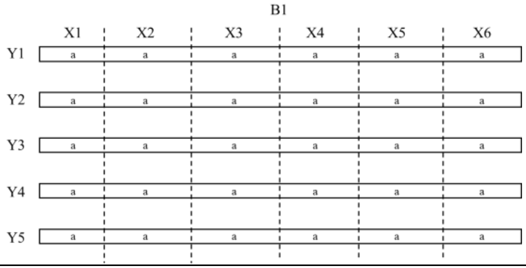
Physical (Three Segment)



Physical (Four Segment)



Physical (Six Segment)



13. Bridge 13C

Image

Non-Physical (One Segment)

	B1
Y1	2 - c
Y2	2 - c
Y3	2 - c
Y4	0 - a
Y5	2 - c

Physical (Two Segment)

B1

	X1	X2
Y1	c	a
Y2	c	a
Y3	c	a
Y4	a	a
Y5	c	a

Physical (Three Segment)

B1

	X1	X2	X3
Y1	c	a	a
Y2	c	a	a
Y3	c	a	a
Y4	a	a	a
Y5	c	a	a

Physical (Four Segment)

B1

	X1	X2	X3	X4
Y1	c	a	a	a
Y2	c	a	a	a
Y3	c	a	a	a
Y4	a	a	a	a
Y5	c	a	a	a

Physical (Six Segment)

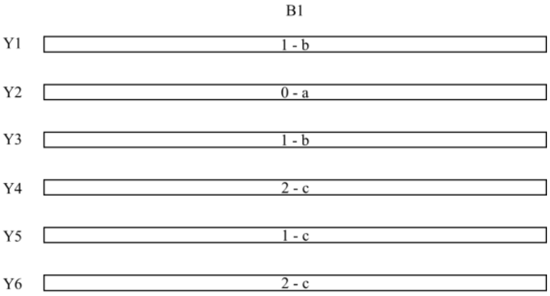
B1

	X1	X2	X3	X4	X5	X6
Y1	c	c	a	a	a	a
Y2	c	c	a	a	a	a
Y3	c	c	a	a	a	a
Y4	a	a	a	a	a	a
Y5	c	a	a	a	a	a

14. Bridge 14C

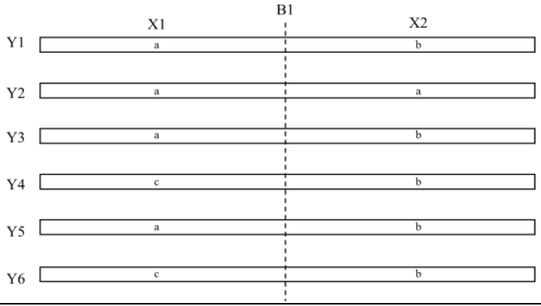
Image

Non-Physical (One Segment)



	B1
Y1	1 - b
Y2	0 - a
Y3	1 - b
Y4	2 - c
Y5	1 - c
Y6	2 - c

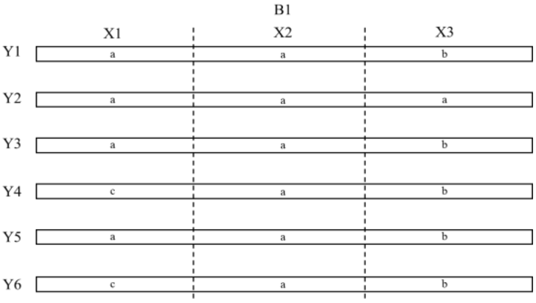
Physical (Two Segment)



B1

	X1	X2
Y1	a	b
Y2	a	a
Y3	a	b
Y4	c	b
Y5	a	b
Y6	c	b

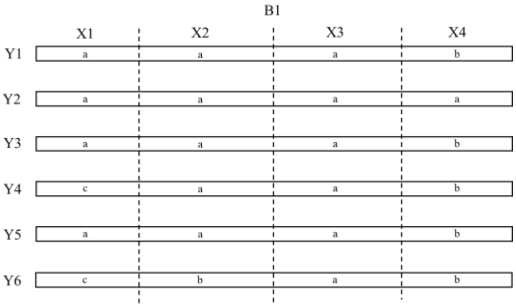
Physical (Three Segment)



B1

	X1	X2	X3
Y1	a	a	b
Y2	a	a	a
Y3	a	a	b
Y4	c	a	b
Y5	a	a	b
Y6	c	a	b

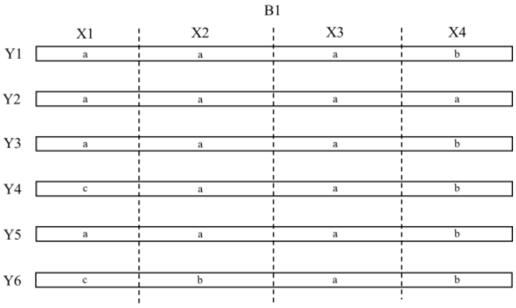
Physical (Four Segment)



B1

	X1	X2	X3	X4
Y1	a	a	a	b
Y2	a	a	a	a
Y3	a	a	a	b
Y4	c	a	a	b
Y5	a	a	a	b
Y6	c	b	a	b

Physical (Six Segment)



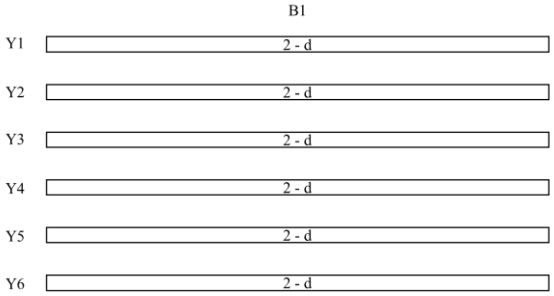
B1

	X1	X2	X3	X4
Y1	a	a	a	b
Y2	a	a	a	a
Y3	a	a	a	b
Y4	c	a	a	b
Y5	a	a	a	b
Y6	c	b	a	b

15. Bridge 15C

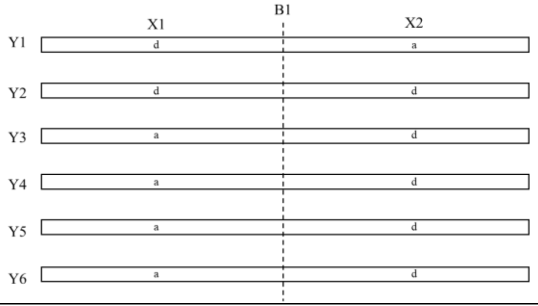
Image

Non-Physical (One Segment)



	B1
Y1	2 - d
Y2	2 - d
Y3	2 - d
Y4	2 - d
Y5	2 - d
Y6	2 - d

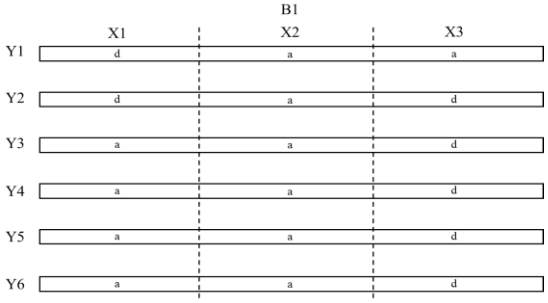
Physical (Two Segment)



B1

	X1	X2
Y1	d	a
Y2	d	d
Y3	a	d
Y4	a	d
Y5	a	d
Y6	a	d

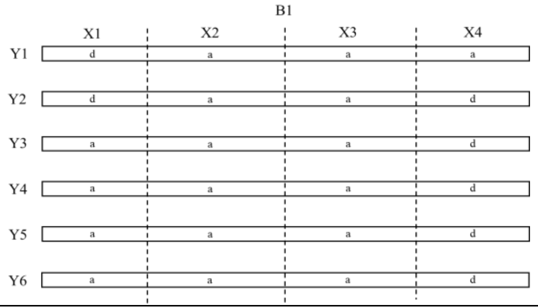
Physical (Three Segment)



B1

	X1	X2	X3
Y1	d	a	a
Y2	d	a	d
Y3	a	a	d
Y4	a	a	d
Y5	a	a	d
Y6	a	a	d

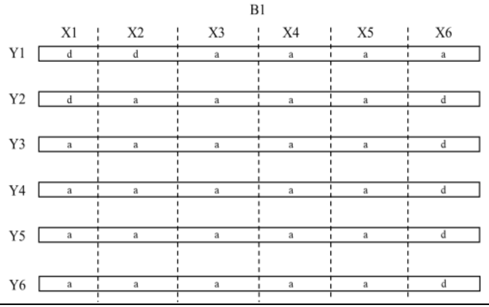
Physical (Four Segment)



B1

	X1	X2	X3	X4
Y1	d	a	a	a
Y2	d	a	a	d
Y3	a	a	a	d
Y4	a	a	a	d
Y5	a	a	a	d
Y6	a	a	a	d

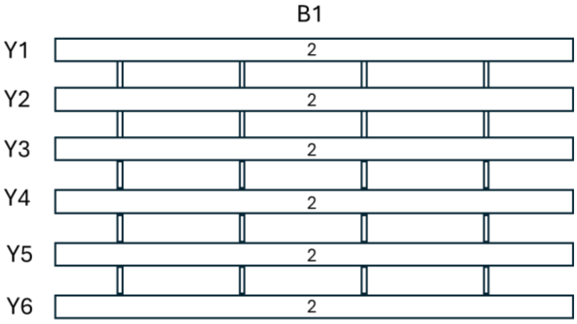
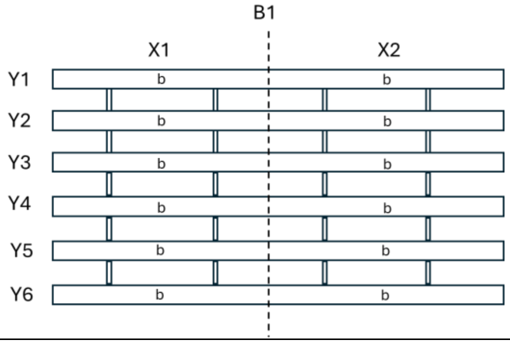
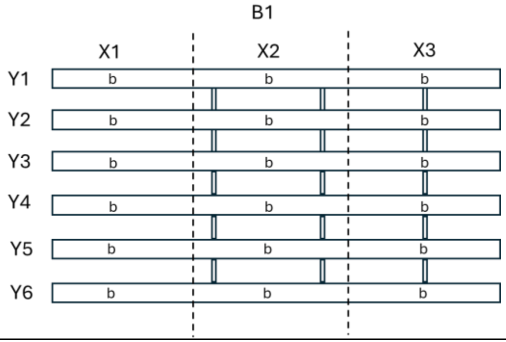
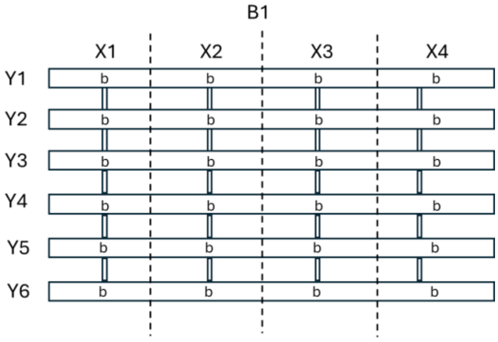
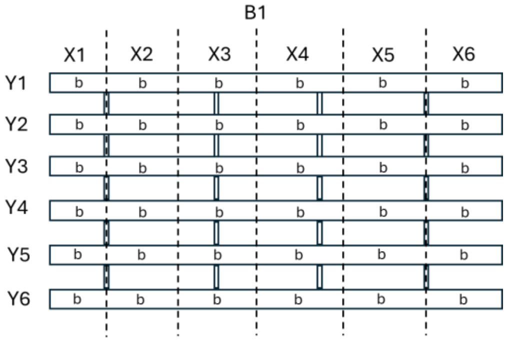
Physical (Six Segment)



B1

	X1	X2	X3	X4	X5	X6
Y1	d	d	a	a	a	a
Y2	d	a	a	a	a	d
Y3	a	a	a	a	a	d
Y4	a	a	a	a	a	d
Y5	a	a	a	a	a	d
Y6	a	a	a	a	a	d

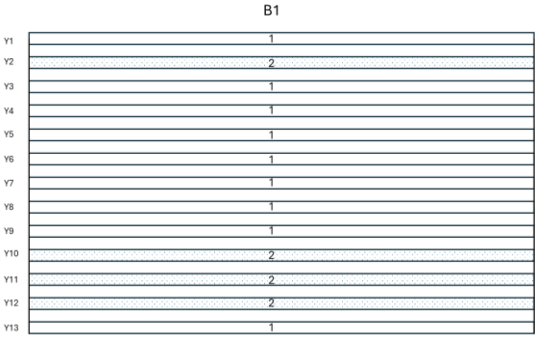
16. Bridge 1S

Image 	Non-Physical (One Segment) 
Physical (Two Segment)  	Physical (Three Segment) 
Physical (Four Segment)  	Physical (Six Segment) 

17. Bridge 2S

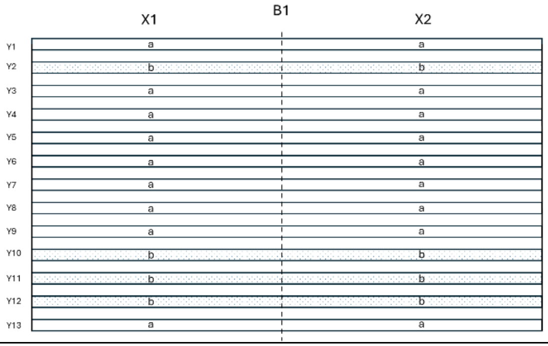
Image

Non-Physical (One Segment)



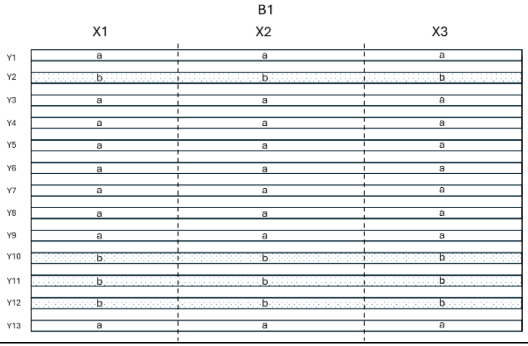
	B1
Y1	1
Y2	2
Y3	1
Y4	1
Y5	1
Y6	1
Y7	1
Y8	1
Y9	1
Y10	2
Y11	2
Y12	2
Y13	1

Physical (Two Segment)



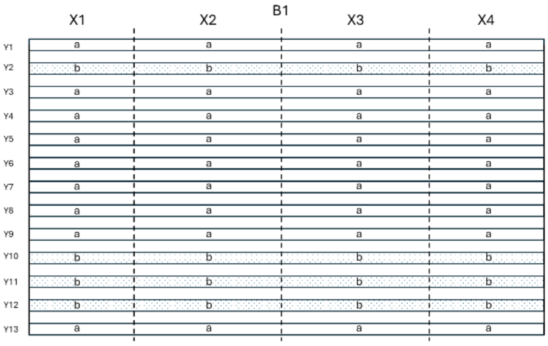
	B1	
	X1	X2
Y1	a	a
Y2	b	b
Y3	a	a
Y4	a	a
Y5	a	a
Y6	a	a
Y7	a	a
Y8	a	a
Y9	a	a
Y10	b	b
Y11	b	b
Y12	b	b
Y13	a	a

Physical (Three Segment)



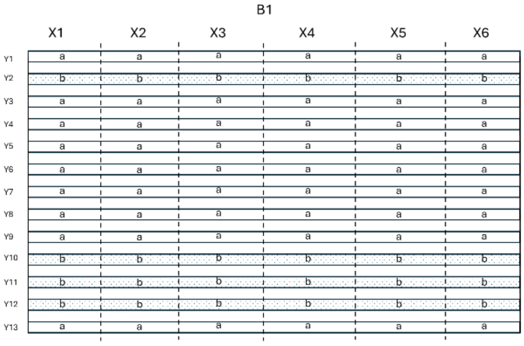
		B1	
	X1	X2	X3
Y1	a	a	a
Y2	b	b	b
Y3	a	a	a
Y4	a	a	a
Y5	a	a	a
Y6	a	a	a
Y7	a	a	a
Y8	a	a	a
Y9	a	a	a
Y10	b	b	b
Y11	b	b	b
Y12	b	b	b
Y13	a	a	a

Physical (Four Segment)



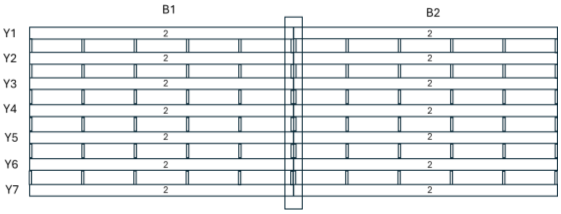
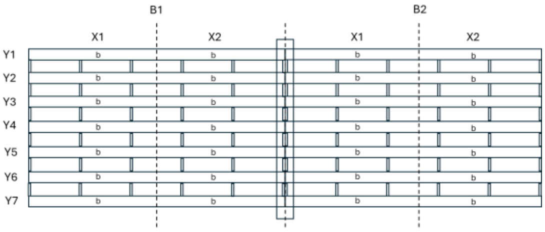
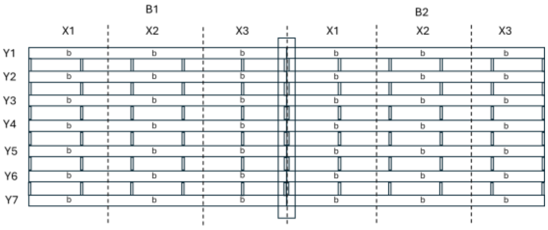
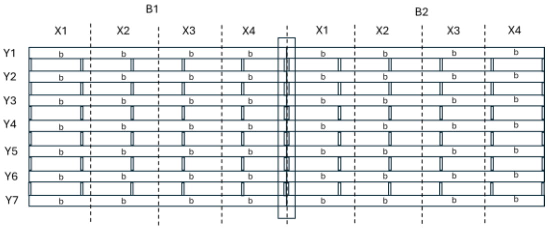
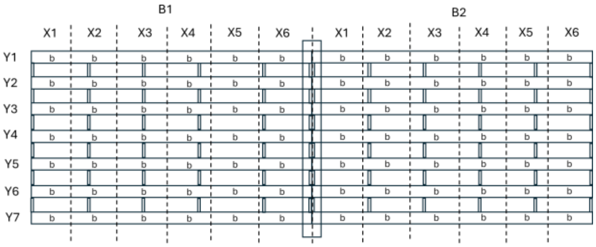
		B1		
	X1	X2	X3	X4
Y1	a	a	a	a
Y2	b	b	b	b
Y3	a	a	a	a
Y4	a	a	a	a
Y5	a	a	a	a
Y6	a	a	a	a
Y7	a	a	a	a
Y8	a	a	a	a
Y9	a	a	a	a
Y10	b	b	b	b
Y11	b	b	b	b
Y12	b	b	b	b
Y13	a	a	a	a

Physical (Six Segment)



			B1			
	X1	X2	X3	X4	X5	X6
Y1	a	a	a	a	a	a
Y2	b	b	b	b	b	b
Y3	a	a	a	a	a	a
Y4	a	a	a	a	a	a
Y5	a	a	a	a	a	a
Y6	a	a	a	a	a	a
Y7	a	a	a	a	a	a
Y8	a	a	a	a	a	a
Y9	a	a	a	a	a	a
Y10	b	b	b	b	b	b
Y11	b	b	b	b	b	b
Y12	b	b	b	b	b	b
Y13	a	a	a	a	a	a

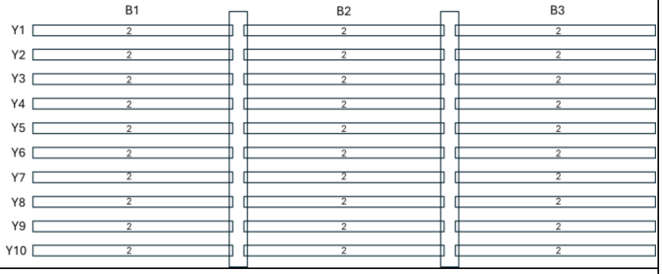
18. Bridge 3S

Image 	Non-Physical (One Segment) 
Physical (Two Segment)  	Physical (Three Segment) 
Physical (Four Segment)  	Physical (Six Segment) 

19. Bridge 4S

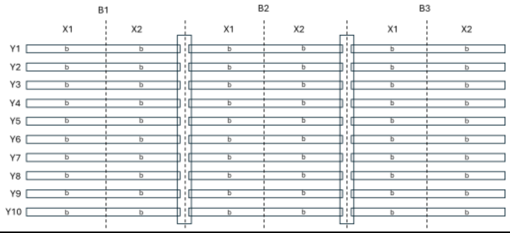
Image

Non-Physical (One Segment)



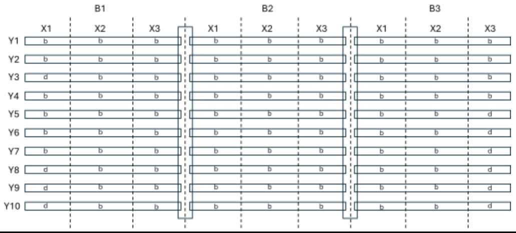
	B1	B2	B3
Y1	2	2	2
Y2	2	2	2
Y3	2	2	2
Y4	2	2	2
Y5	2	2	2
Y6	2	2	2
Y7	2	2	2
Y8	2	2	2
Y9	2	2	2
Y10	2	2	2

Physical (Two Segment)



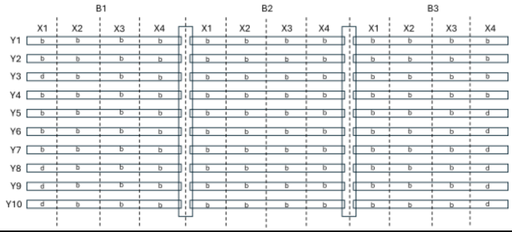
	B1		B2		B3	
	X1	X2	X1	X2	X1	X2
Y1	b	b	b	b	b	b
Y2	b	b	b	b	b	b
Y3	b	b	b	b	b	b
Y4	b	b	b	b	b	b
Y5	b	b	b	b	b	b
Y6	b	b	b	b	b	b
Y7	b	b	b	b	b	b
Y8	b	b	b	b	b	b
Y9	b	b	b	b	b	b
Y10	b	b	b	b	b	b

Physical (Three Segment)



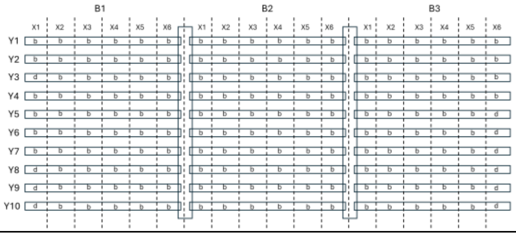
	B1			B2			B3		
	X1	X2	X3	X1	X2	X3	X1	X2	X3
Y1	b	b	b	b	b	b	b	b	b
Y2	b	b	b	b	b	b	b	b	b
Y3	d	b	b	b	b	b	b	b	b
Y4	b	b	b	b	b	b	b	b	b
Y5	b	b	b	b	b	b	b	b	d
Y6	b	b	b	b	b	b	b	b	d
Y7	b	b	b	b	b	b	b	b	d
Y8	d	b	b	b	b	b	b	b	d
Y9	d	b	b	b	b	b	b	b	d
Y10	d	b	b	b	b	b	b	b	d

Physical (Four Segment)



	B1				B2				B3			
	X1	X2	X3	X4	X1	X2	X3	X4	X1	X2	X3	X4
Y1	b	b	b	b	b	b	b	b	b	b	b	b
Y2	b	b	b	b	b	b	b	b	b	b	b	b
Y3	d	b	b	b	b	b	b	b	b	b	b	b
Y4	b	b	b	b	b	b	b	b	b	b	b	b
Y5	b	b	b	b	b	b	b	b	b	b	b	d
Y6	b	b	b	b	b	b	b	b	b	b	b	d
Y7	b	b	b	b	b	b	b	b	b	b	b	d
Y8	d	b	b	b	b	b	b	b	b	b	b	d
Y9	d	b	b	b	b	b	b	b	b	b	b	d
Y10	d	b	b	b	b	b	b	b	b	b	b	d

Physical (Six Segment)

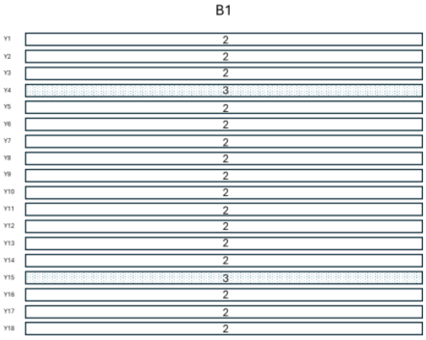


	B1						B2						B3					
	X1	X2	X3	X4	X5	X6	X1	X2	X3	X4	X5	X6	X1	X2	X3	X4	X5	X6
Y1	b	b	b	b	b	b	b	b	b	b	b	b	b	b	b	b	b	b
Y2	b	b	b	b	b	b	b	b	b	b	b	b	b	b	b	b	b	b
Y3	d	b	b	b	b	b	b	b	b	b	b	b	b	b	b	b	b	b
Y4	b	b	b	b	b	b	b	b	b	b	b	b	b	b	b	b	b	b
Y5	b	b	b	b	b	b	b	b	b	b	b	b	b	b	b	b	b	d
Y6	b	b	b	b	b	b	b	b	b	b	b	b	b	b	b	b	b	d
Y7	b	b	b	b	b	b	b	b	b	b	b	b	b	b	b	b	b	d
Y8	d	b	b	b	b	b	b	b	b	b	b	b	b	b	b	b	b	d
Y9	d	b	b	b	b	b	b	b	b	b	b	b	b	b	b	b	b	d
Y10	d	b	b	b	b	b	b	b	b	b	b	b	b	b	b	b	b	d

20. Bridge 5S

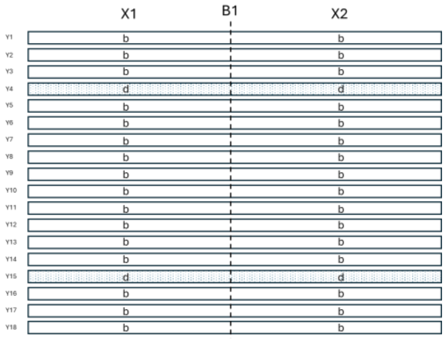
Image

Non-Physical (One Segment)



	B1
Y1	2
Y2	2
Y3	2
Y4	3
Y5	2
Y6	2
Y7	2
Y8	2
Y9	2
Y10	2
Y11	2
Y12	2
Y13	2
Y14	2
Y15	3
Y16	2
Y17	2
Y18	2

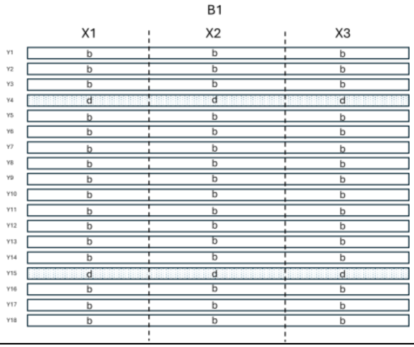
Physical (Two Segment)



B1

	X1	X2
Y1	b	b
Y2	b	b
Y3	b	b
Y4	d	d
Y5	b	b
Y6	b	b
Y7	b	b
Y8	b	b
Y9	b	b
Y10	b	b
Y11	b	b
Y12	b	b
Y13	b	b
Y14	b	b
Y15	d	d
Y16	b	b
Y17	b	b
Y18	b	b

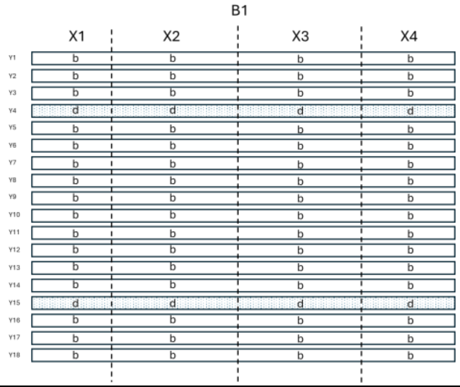
Physical (Three Segment)



B1

	X1	X2	X3
Y1	b	b	b
Y2	b	b	b
Y3	b	b	b
Y4	d	d	d
Y5	b	b	b
Y6	b	b	b
Y7	b	b	b
Y8	b	b	b
Y9	b	b	b
Y10	b	b	b
Y11	b	b	b
Y12	b	b	b
Y13	b	b	b
Y14	b	b	b
Y15	d	d	d
Y16	b	b	b
Y17	b	b	b
Y18	b	b	b

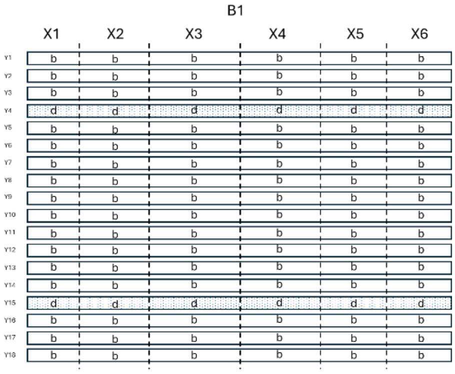
Physical (Four Segment)



B1

	X1	X2	X3	X4
Y1	b	b	b	b
Y2	b	b	b	b
Y3	b	b	b	b
Y4	d	d	d	d
Y5	b	b	b	b
Y6	b	b	b	b
Y7	b	b	b	b
Y8	b	b	b	b
Y9	b	b	b	b
Y10	b	b	b	b
Y11	b	b	b	b
Y12	b	b	b	b
Y13	b	b	b	b
Y14	b	b	b	b
Y15	d	d	d	d
Y16	b	b	b	b
Y17	b	b	b	b
Y18	b	b	b	b

Physical (Six Segment)



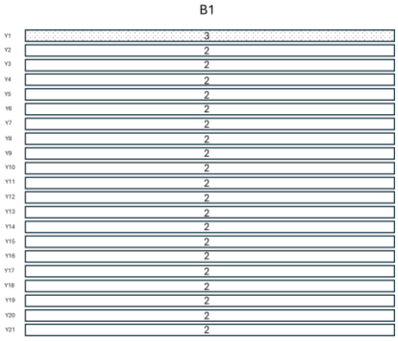
B1

	X1	X2	X3	X4	X5	X6
Y1	b	b	b	b	b	b
Y2	b	b	b	b	b	b
Y3	b	b	b	b	b	b
Y4	d	d	d	d	d	d
Y5	b	b	b	b	b	b
Y6	b	b	b	b	b	b
Y7	b	b	b	b	b	b
Y8	b	b	b	b	b	b
Y9	b	b	b	b	b	b
Y10	b	b	b	b	b	b
Y11	b	b	b	b	b	b
Y12	b	b	b	b	b	b
Y13	b	b	b	b	b	b
Y14	b	b	b	b	b	b
Y15	d	d	d	d	d	d
Y16	b	b	b	b	b	b
Y17	b	b	b	b	b	b
Y18	b	b	b	b	b	b

21. Bridge 6S

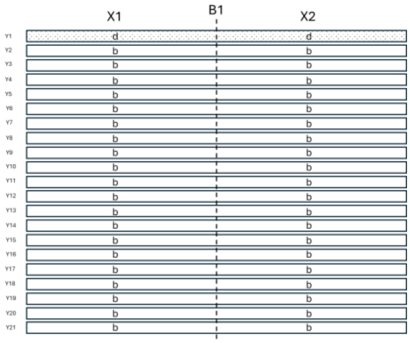
Image

Non-Physical (One Segment)



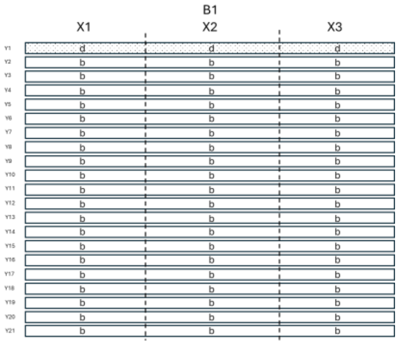
	B1
Y1	3
Y2	2
Y3	2
Y4	2
Y5	2
Y6	2
Y7	2
Y8	2
Y9	2
Y10	2
Y11	2
Y12	2
Y13	2
Y14	2
Y15	2
Y16	2
Y17	2
Y18	2
Y19	2
Y20	2
Y21	2

Physical (Two Segment)



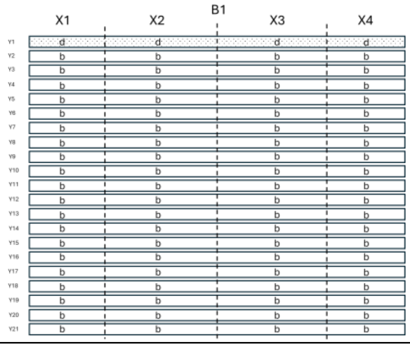
	B1	
	X1	X2
Y1	d	d
Y2	b	b
Y3	b	b
Y4	b	b
Y5	b	b
Y6	b	b
Y7	b	b
Y8	b	b
Y9	b	b
Y10	b	b
Y11	b	b
Y12	b	b
Y13	b	b
Y14	b	b
Y15	b	b
Y16	b	b
Y17	b	b
Y18	b	b
Y19	b	b
Y20	b	b
Y21	b	b

Physical (Three Segment)



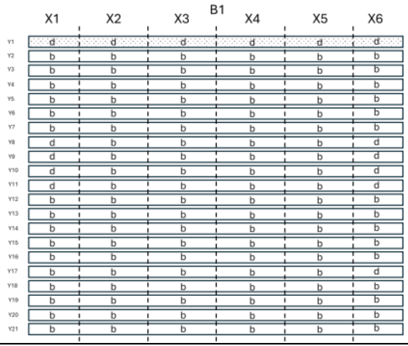
	B1		
	X1	X2	X3
Y1	d	d	d
Y2	b	b	b
Y3	b	b	b
Y4	b	b	b
Y5	b	b	b
Y6	b	b	b
Y7	b	b	b
Y8	b	b	b
Y9	b	b	b
Y10	b	b	b
Y11	b	b	b
Y12	b	b	b
Y13	b	b	b
Y14	b	b	b
Y15	b	b	b
Y16	b	b	b
Y17	b	b	b
Y18	b	b	b
Y19	b	b	b
Y20	b	b	b
Y21	b	b	b

Physical (Four Segment)



	B1			
	X1	X2	X3	X4
Y1	d	d	d	d
Y2	b	b	b	b
Y3	b	b	b	b
Y4	b	b	b	b
Y5	b	b	b	b
Y6	b	b	b	b
Y7	b	b	b	b
Y8	b	b	b	b
Y9	b	b	b	b
Y10	b	b	b	b
Y11	b	b	b	b
Y12	b	b	b	b
Y13	b	b	b	b
Y14	b	b	b	b
Y15	b	b	b	b
Y16	b	b	b	b
Y17	b	b	b	b
Y18	b	b	b	b
Y19	b	b	b	b
Y20	b	b	b	b
Y21	b	b	b	b

Physical (Six Segment)



	B1					
	X1	X2	X3	X4	X5	X6
Y1	d	d	d	d	d	d
Y2	b	b	b	b	b	b
Y3	b	b	b	b	b	b
Y4	b	b	b	b	b	b
Y5	b	b	b	b	b	b
Y6	b	b	b	b	b	b
Y7	b	b	b	b	b	b
Y8	d	b	b	b	b	d
Y9	d	b	b	b	b	d
Y10	d	b	b	b	b	d
Y11	d	b	b	b	b	d
Y12	b	b	b	b	b	b
Y13	b	b	b	b	b	b
Y14	b	b	b	b	b	b
Y15	b	b	b	b	b	b
Y16	b	b	b	b	b	b
Y17	b	b	b	b	b	d
Y18	b	b	b	b	b	b
Y19	b	b	b	b	b	b
Y20	b	b	b	b	b	b
Y21	b	b	b	b	b	b

22. Bridge 7S

Image

Non-Physical (One Segment)

	B1
Y1	2
Y2	2
Y3	2
Y4	2
Y5	3
Y6	2
Y7	2
Y8	2
Y9	2
Y10	2
Y11	3
Y12	2
Y13	2
Y14	3
Y15	3
Y16	3
Y17	3
Y18	2
Y19	2

Physical (Two Segment)

B1

	X1	X2
Y1	b	b
Y2	b	b
Y3	b	b
Y4	b	b
Y5	d	d
Y6	b	b
Y7	b	b
Y8	b	b
Y9	b	b
Y10	b	b
Y11	d	d
Y12	b	b
Y13	b	b
Y14	d	d
Y15	d	d
Y16	d	d
Y17	d	d
Y18	b	b
Y19	b	b

Physical (Three Segment)

B1

	X1	X2	X3
Y1	b	b	b
Y2	b	b	b
Y3	b	b	b
Y4	b	b	b
Y5	d	d	d
Y6	b	b	b
Y7	b	b	b
Y8	b	b	b
Y9	b	b	b
Y10	b	b	b
Y11	d	d	d
Y12	b	b	b
Y13	b	b	b
Y14	d	d	d
Y15	d	d	d
Y16	d	d	d
Y17	d	d	d
Y18	b	b	b
Y19	b	b	b

Physical (Four Segment)

B1

	X1	X2	X3	X4
Y1	b	b	b	b
Y2	b	b	b	b
Y3	b	b	b	b
Y4	b	b	b	b
Y5	d	d	d	d
Y6	b	b	b	b
Y7	b	b	b	b
Y8	b	b	b	b
Y9	b	b	b	b
Y10	b	b	b	b
Y11	d	d	d	d
Y12	b	b	b	b
Y13	b	b	b	b
Y14	d	d	d	d
Y15	d	d	d	d
Y16	d	d	d	d
Y17	d	d	d	d
Y18	b	b	b	b
Y19	b	b	b	b

Physical (Six Segment)

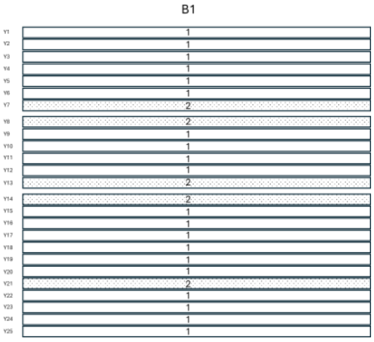
B1

	X1	X2	X3	X4	X5	X6
Y1	b	b	b	b	b	b
Y2	b	b	b	b	b	b
Y3	b	b	b	b	b	b
Y4	b	b	b	b	b	b
Y5	d	d	d	d	d	d
Y6	b	b	b	b	b	b
Y7	b	b	b	b	b	b
Y8	b	b	b	b	b	b
Y9	b	b	b	b	b	b
Y10	b	b	b	b	b	b
Y11	d	d	d	d	d	d
Y12	b	b	b	b	b	b
Y13	b	b	b	b	b	b
Y14	d	d	d	d	d	d
Y15	d	d	d	d	d	d
Y16	d	d	d	d	d	d
Y17	d	d	d	d	d	d
Y18	b	b	b	b	b	b
Y19	b	b	b	b	b	b

23. Bridge 8S

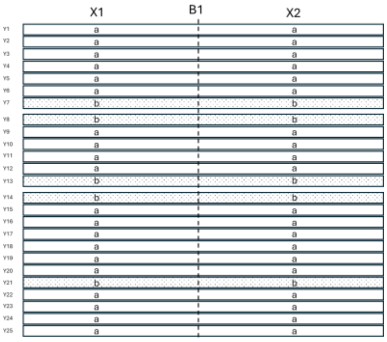
Image

Non-Physical (One Segment)



	B1
Y1	1
Y2	1
Y3	1
Y4	1
Y5	1
Y6	1
Y7	2
Y8	2
Y9	1
Y10	1
Y11	1
Y12	1
Y13	2
Y14	2
Y15	1
Y16	1
Y17	1
Y18	1
Y19	1
Y20	1
Y21	2
Y22	1
Y23	1
Y24	1
Y25	1

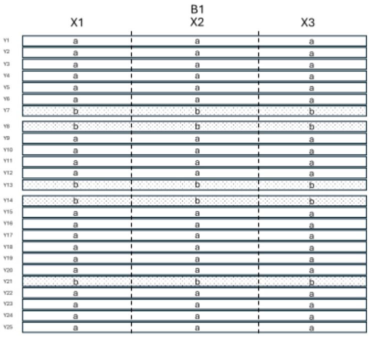
Physical (Two Segment)



B1

	X1	X2
Y1	a	a
Y2	a	a
Y3	a	a
Y4	a	a
Y5	a	a
Y6	a	a
Y7	b	b
Y8	b	b
Y9	a	a
Y10	a	a
Y11	a	a
Y12	a	a
Y13	b	b
Y14	b	b
Y15	a	a
Y16	a	a
Y17	a	a
Y18	a	a
Y19	a	a
Y20	a	a
Y21	b	b
Y22	a	a
Y23	a	a
Y24	a	a
Y25	a	a

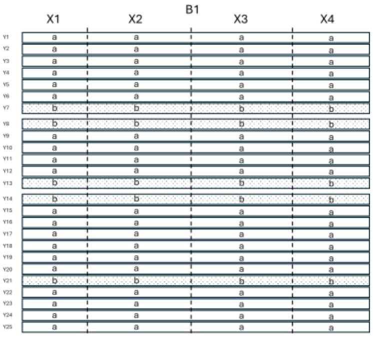
Physical (Three Segment)



B1

	X1	X2	X3
Y1	a	a	a
Y2	a	a	a
Y3	a	a	a
Y4	a	a	a
Y5	a	a	a
Y6	a	a	a
Y7	b	b	b
Y8	b	b	b
Y9	a	a	a
Y10	a	a	a
Y11	a	a	a
Y12	a	a	a
Y13	b	b	b
Y14	b	b	b
Y15	a	a	a
Y16	a	a	a
Y17	a	a	a
Y18	a	a	a
Y19	a	a	a
Y20	a	a	a
Y21	b	b	b
Y22	a	a	a
Y23	a	a	a
Y24	a	a	a
Y25	a	a	a

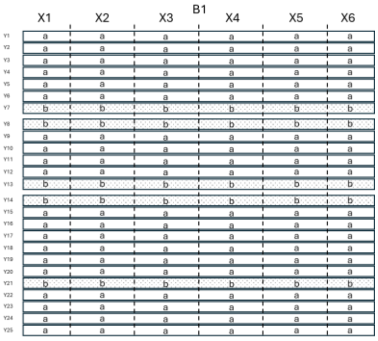
Physical (Four Segment)



B1

	X1	X2	X3	X4
Y1	a	a	a	a
Y2	a	a	a	a
Y3	a	a	a	a
Y4	a	a	a	a
Y5	a	a	a	a
Y6	a	a	a	a
Y7	b	b	b	b
Y8	b	b	b	b
Y9	a	a	a	a
Y10	a	a	a	a
Y11	a	a	a	a
Y12	a	a	a	a
Y13	b	b	b	b
Y14	b	b	b	b
Y15	a	a	a	a
Y16	a	a	a	a
Y17	a	a	a	a
Y18	a	a	a	a
Y19	a	a	a	a
Y20	a	a	a	a
Y21	b	b	b	b
Y22	a	a	a	a
Y23	a	a	a	a
Y24	a	a	a	a
Y25	a	a	a	a

Physical (Six Segment)



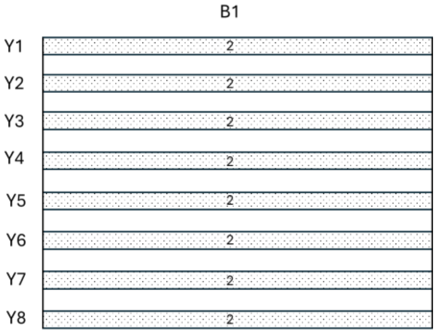
B1

	X1	X2	X3	X4	X5	X6
Y1	a	a	a	a	a	a
Y2	a	a	a	a	a	a
Y3	a	a	a	a	a	a
Y4	a	a	a	a	a	a
Y5	a	a	a	a	a	a
Y6	a	a	a	a	a	a
Y7	b	b	b	b	b	b
Y8	b	b	b	b	b	b
Y9	a	a	a	a	a	a
Y10	a	a	a	a	a	a
Y11	a	a	a	a	a	a
Y12	a	a	a	a	a	a
Y13	b	b	b	b	b	b
Y14	b	b	b	b	b	b
Y15	a	a	a	a	a	a
Y16	a	a	a	a	a	a
Y17	a	a	a	a	a	a
Y18	a	a	a	a	a	a
Y19	a	a	a	a	a	a
Y20	a	a	a	a	a	a
Y21	b	b	b	b	b	b
Y22	a	a	a	a	a	a
Y23	a	a	a	a	a	a
Y24	a	a	a	a	a	a
Y25	a	a	a	a	a	a

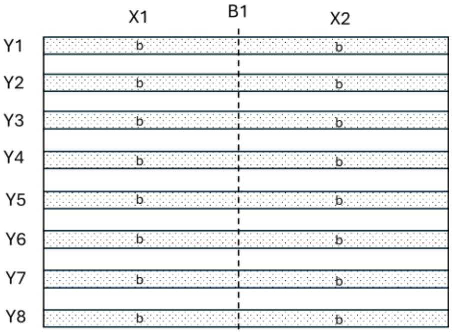
24. Bridge 9S

Image

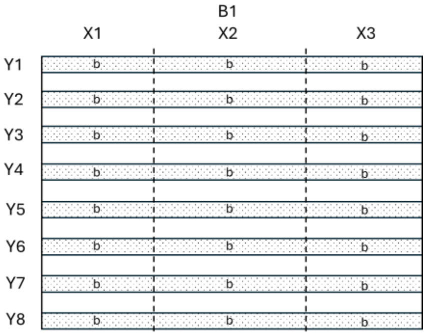
Non-Physical (One Segment)



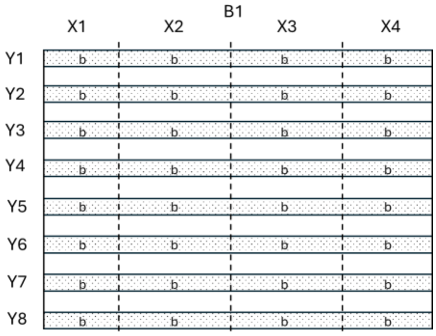
Physical (Two Segment)



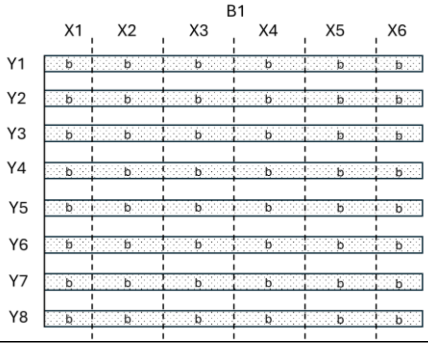
Physical (Three Segment)



Physical (Four Segment)



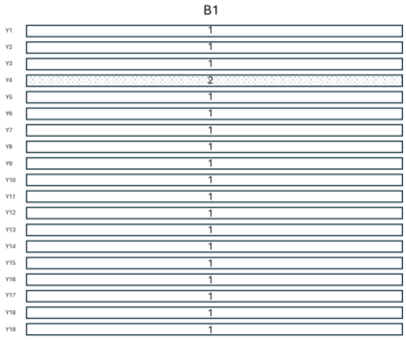
Physical (Six Segment)



25. Bridge 10S

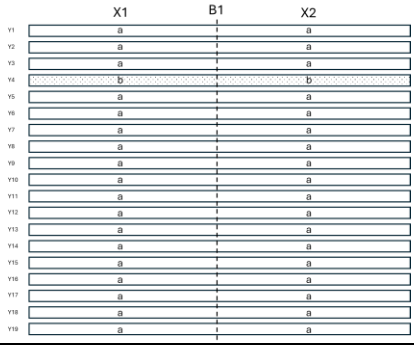
Image

Non-Physical (One Segment)



	B1
Y1	1
Y2	1
Y3	1
Y4	2
Y5	1
Y6	1
Y7	1
Y8	1
Y9	1
Y10	1
Y11	1
Y12	1
Y13	1
Y14	1
Y15	1
Y16	1
Y17	1
Y18	1
Y19	1

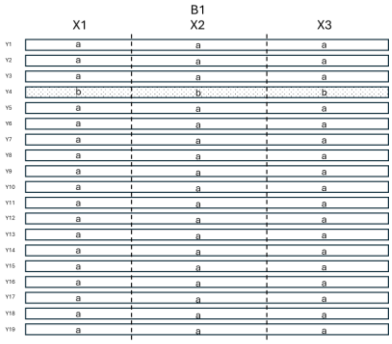
Physical (Two Segment)



B1

	X1	X2
Y1	a	a
Y2	a	a
Y3	a	a
Y4	b	b
Y5	a	a
Y6	a	a
Y7	a	a
Y8	a	a
Y9	a	a
Y10	a	a
Y11	a	a
Y12	a	a
Y13	a	a
Y14	a	a
Y15	a	a
Y16	a	a
Y17	a	a
Y18	a	a
Y19	a	a

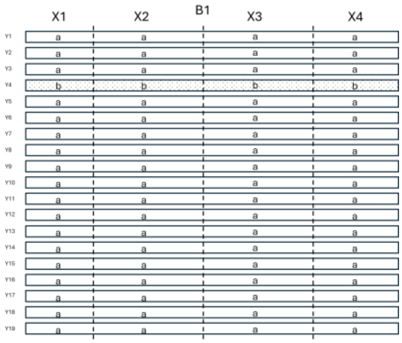
Physical (Three Segment)



B1

	X1	X2	X3
Y1	a	a	a
Y2	a	a	a
Y3	a	a	a
Y4	b	b	b
Y5	a	a	a
Y6	a	a	a
Y7	a	a	a
Y8	a	a	a
Y9	a	a	a
Y10	a	a	a
Y11	a	a	a
Y12	a	a	a
Y13	a	a	a
Y14	a	a	a
Y15	a	a	a
Y16	a	a	a
Y17	a	a	a
Y18	a	a	a
Y19	a	a	a

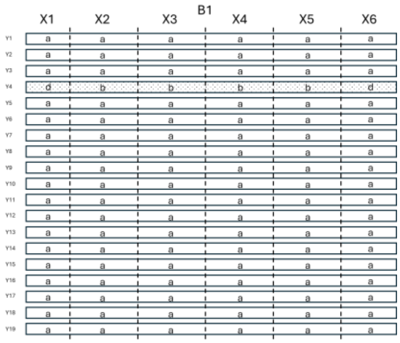
Physical (Four Segment)



B1

	X1	X2	X3	X4
Y1	a	a	a	a
Y2	a	a	a	a
Y3	a	a	a	a
Y4	b	b	b	b
Y5	a	a	a	a
Y6	a	a	a	a
Y7	a	a	a	a
Y8	a	a	a	a
Y9	a	a	a	a
Y10	a	a	a	a
Y11	a	a	a	a
Y12	a	a	a	a
Y13	a	a	a	a
Y14	a	a	a	a
Y15	a	a	a	a
Y16	a	a	a	a
Y17	a	a	a	a
Y18	a	a	a	a
Y19	a	a	a	a

Physical (Six Segment)



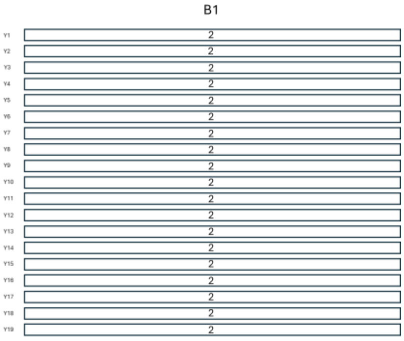
B1

	X1	X2	X3	X4	X5	X6
Y1	a	a	a	a	a	a
Y2	a	a	a	a	a	a
Y3	a	a	a	a	a	a
Y4	d	b	b	b	b	d
Y5	a	a	a	a	a	a
Y6	a	a	a	a	a	a
Y7	a	a	a	a	a	a
Y8	a	a	a	a	a	a
Y9	a	a	a	a	a	a
Y10	a	a	a	a	a	a
Y11	a	a	a	a	a	a
Y12	a	a	a	a	a	a
Y13	a	a	a	a	a	a
Y14	a	a	a	a	a	a
Y15	a	a	a	a	a	a
Y16	a	a	a	a	a	a
Y17	a	a	a	a	a	a
Y18	a	a	a	a	a	a
Y19	a	a	a	a	a	a

26. Bridge 11S

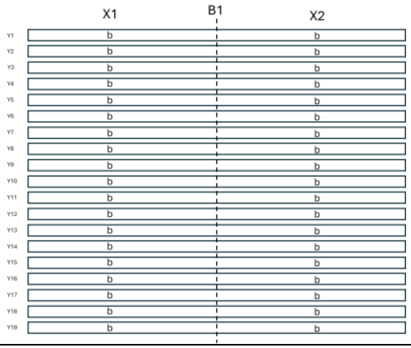
Image

Non-Physical (One Segment)



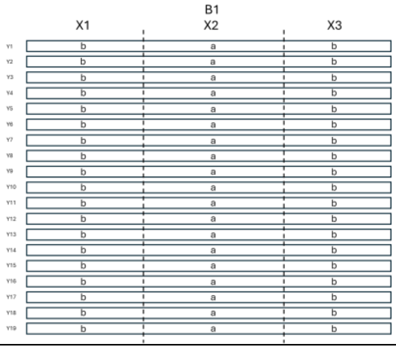
	B1
Y1	2
Y2	2
Y3	2
Y4	2
Y5	2
Y6	2
Y7	2
Y8	2
Y9	2
Y10	2
Y11	2
Y12	2
Y13	2
Y14	2
Y15	2
Y16	2
Y17	2
Y18	2
Y19	2

Physical (Two Segment)



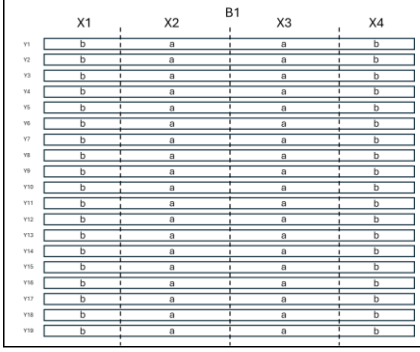
	X1	X2
Y1	b	b
Y2	b	b
Y3	b	b
Y4	b	b
Y5	b	b
Y6	b	b
Y7	b	b
Y8	b	b
Y9	b	b
Y10	b	b
Y11	b	b
Y12	b	b
Y13	b	b
Y14	b	b
Y15	b	b
Y16	b	b
Y17	b	b
Y18	b	b
Y19	b	b

Physical (Three Segment)



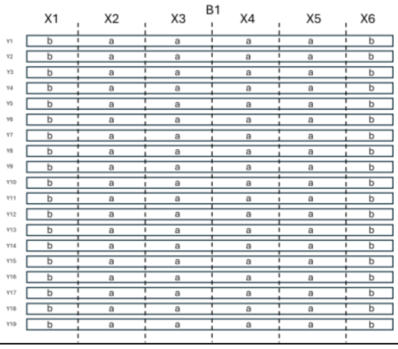
	X1	X2	X3
Y1	b	a	b
Y2	b	a	b
Y3	b	a	b
Y4	b	a	b
Y5	b	a	b
Y6	b	a	b
Y7	b	a	b
Y8	b	a	b
Y9	b	a	b
Y10	b	a	b
Y11	b	a	b
Y12	b	a	b
Y13	b	a	b
Y14	b	a	b
Y15	b	a	b
Y16	b	a	b
Y17	b	a	b
Y18	b	a	b
Y19	b	a	b

Physical (Four Segment)



	X1	X2	X3	X4
Y1	b	a	a	b
Y2	b	a	a	b
Y3	b	a	a	b
Y4	b	a	a	b
Y5	b	a	a	b
Y6	b	a	a	b
Y7	b	a	a	b
Y8	b	a	a	b
Y9	b	a	a	b
Y10	b	a	a	b
Y11	b	a	a	b
Y12	b	a	a	b
Y13	b	a	a	b
Y14	b	a	a	b
Y15	b	a	a	b
Y16	b	a	a	b
Y17	b	a	a	b
Y18	b	a	a	b
Y19	b	a	a	b

Physical (Six Segment)

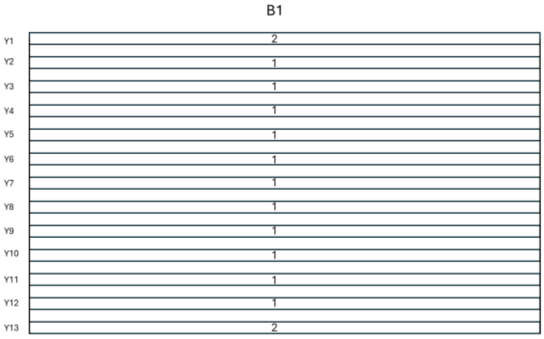


	X1	X2	X3	X4	X5	X6
Y1	b	a	a	a	a	b
Y2	b	a	a	a	a	b
Y3	b	a	a	a	a	b
Y4	b	a	a	a	a	b
Y5	b	a	a	a	a	b
Y6	b	a	a	a	a	b
Y7	b	a	a	a	a	b
Y8	b	a	a	a	a	b
Y9	b	a	a	a	a	b
Y10	b	a	a	a	a	b
Y11	b	a	a	a	a	b
Y12	b	a	a	a	a	b
Y13	b	a	a	a	a	b
Y14	b	a	a	a	a	b
Y15	b	a	a	a	a	b
Y16	b	a	a	a	a	b
Y17	b	a	a	a	a	b
Y18	b	a	a	a	a	b
Y19	b	a	a	a	a	b

27. Bridge 12S

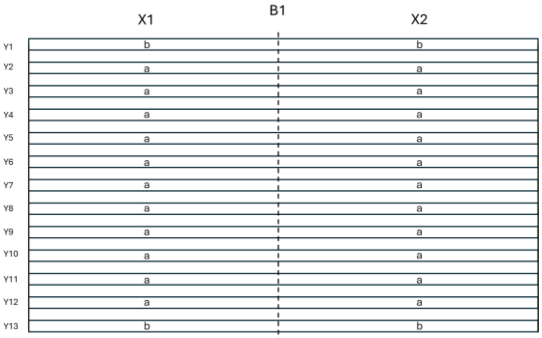
Image

Non-Physical (One Segment)



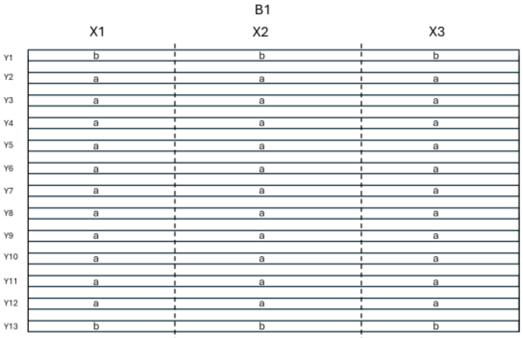
	B1
Y1	2
Y2	1
Y3	1
Y4	1
Y5	1
Y6	1
Y7	1
Y8	1
Y9	1
Y10	1
Y11	1
Y12	1
Y13	2

Physical (Two Segment)



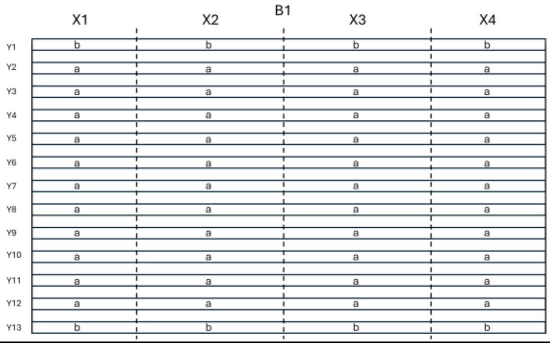
	B1	
	X1	X2
Y1	b	b
Y2	a	a
Y3	a	a
Y4	a	a
Y5	a	a
Y6	a	a
Y7	a	a
Y8	a	a
Y9	a	a
Y10	a	a
Y11	a	a
Y12	a	a
Y13	b	b

Physical (Three Segment)



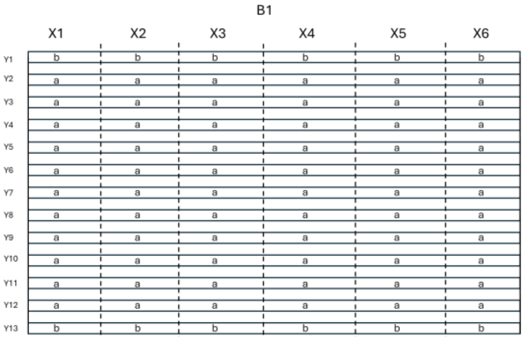
	B1		
	X1	X2	X3
Y1	b	b	b
Y2	a	a	a
Y3	a	a	a
Y4	a	a	a
Y5	a	a	a
Y6	a	a	a
Y7	a	a	a
Y8	a	a	a
Y9	a	a	a
Y10	a	a	a
Y11	a	a	a
Y12	a	a	a
Y13	b	b	b

Physical (Four Segment)



	B1			
	X1	X2	X3	X4
Y1	b	b	b	b
Y2	a	a	a	a
Y3	a	a	a	a
Y4	a	a	a	a
Y5	a	a	a	a
Y6	a	a	a	a
Y7	a	a	a	a
Y8	a	a	a	a
Y9	a	a	a	a
Y10	a	a	a	a
Y11	a	a	a	a
Y12	a	a	a	a
Y13	b	b	b	b

Physical (Six Segment)



	B1					
	X1	X2	X3	X4	X5	X6
Y1	b	b	b	b	b	b
Y2	a	a	a	a	a	a
Y3	a	a	a	a	a	a
Y4	a	a	a	a	a	a
Y5	a	a	a	a	a	a
Y6	a	a	a	a	a	a
Y7	a	a	a	a	a	a
Y8	a	a	a	a	a	a
Y9	a	a	a	a	a	a
Y10	a	a	a	a	a	a
Y11	a	a	a	a	a	a
Y12	a	a	a	a	a	a
Y13	b	b	b	b	b	b

28. Bridge 13S

Image

Non-Physical (One Segment)

	B1
Y1	2
Y2	2
Y3	2
Y4	2
Y5	2
Y6	2
Y7	2
Y8	2
Y9	2
Y10	2
Y11	2
Y12	2
Y13	2

Physical (Two Segment)

	B1	
	X1	X2
Y1	b	b
Y2	b	b
Y3	b	b
Y4	b	b
Y5	b	b
Y6	b	b
Y7	b	b
Y8	b	b
Y9	b	b
Y10	b	b
Y11	b	b
Y12	b	b
Y13	b	b

Physical (Three Segment)

		B1	
	X1	X2	X3
Y1	b	b	b
Y2	b	b	b
Y3	b	b	b
Y4	b	b	b
Y5	b	b	b
Y6	b	b	b
Y7	b	b	b
Y8	b	b	b
Y9	b	b	b
Y10	b	b	b
Y11	b	b	b
Y12	b	b	b
Y13	b	b	b

Physical (Four Segment)

		B1		
	X1	X2	X3	X4
Y1	b	b	b	b
Y2	b	b	b	b
Y3	b	b	b	b
Y4	b	b	b	b
Y5	b	b	b	b
Y6	b	b	b	b
Y7	b	b	b	b
Y8	b	b	b	b
Y9	b	b	b	b
Y10	b	b	b	b
Y11	b	b	b	b
Y12	b	b	b	b
Y13	b	b	b	b

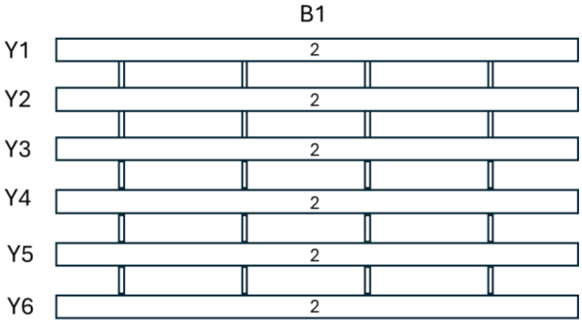
Physical (Six Segment)

			B1			
	X1	X2	X3	X4	X5	X6
Y1	b	b	b	b	b	b
Y2	b	b	b	b	b	b
Y3	b	b	b	b	b	b
Y4	b	b	b	b	b	b
Y5	b	b	b	b	b	b
Y6	b	b	b	b	b	b
Y7	b	b	b	b	b	b
Y8	b	b	b	b	b	b
Y9	b	b	b	b	b	b
Y10	b	b	b	b	b	b
Y11	b	b	b	b	b	b
Y12	b	b	b	b	b	b
Y13	b	b	b	b	b	b

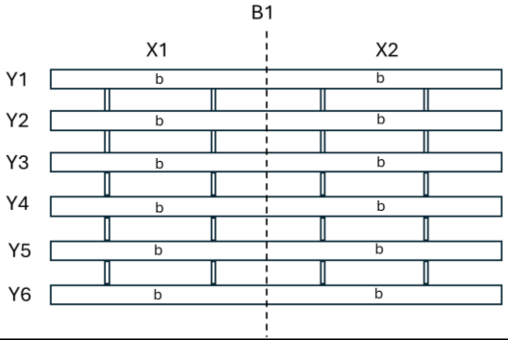
29. Bridge 14S

Image

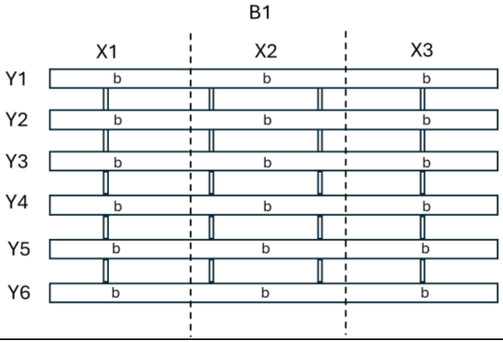
Non-Physical (One Segment)



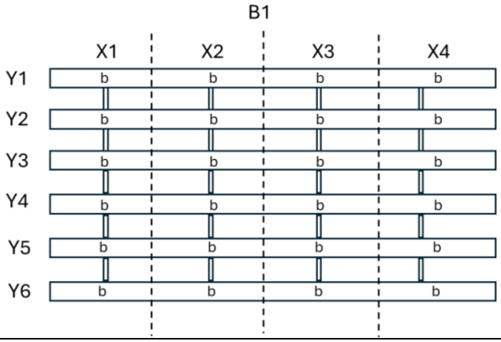
Physical (Two Segment)



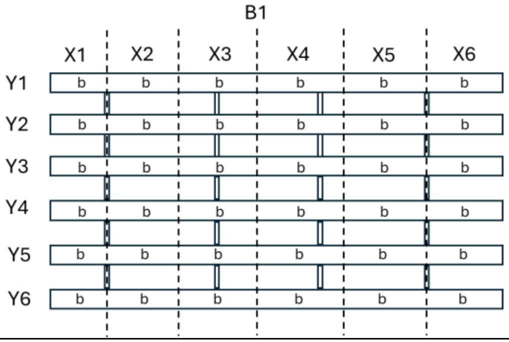
Physical (Three Segment)



Physical (Four Segment)



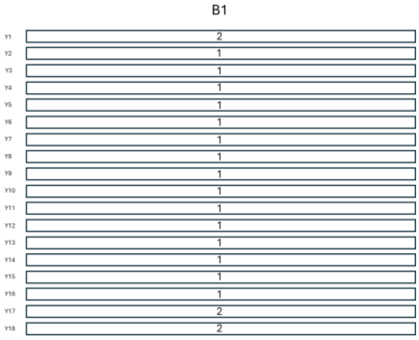
Physical (Six Segment)



30. Bridge 15S

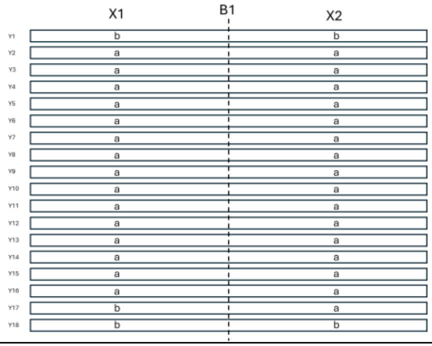
Image

Non-Physical (One Segment)



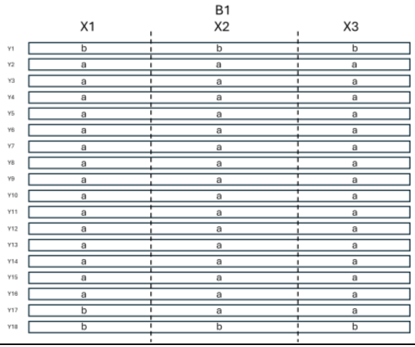
	B1
Y1	2
Y2	1
Y3	1
Y4	1
Y5	1
Y6	1
Y7	1
Y8	1
Y9	1
Y10	1
Y11	1
Y12	1
Y13	1
Y14	1
Y15	1
Y16	1
Y17	2
Y18	2

Physical (Two Segment)



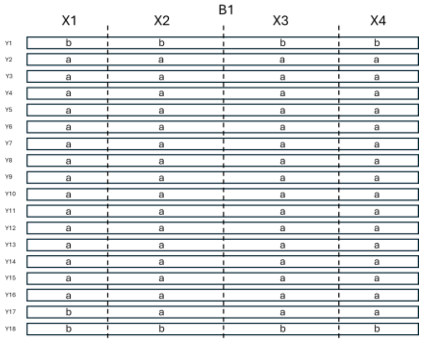
	X1	X2
Y1	b	b
Y2	a	a
Y3	a	a
Y4	a	a
Y5	a	a
Y6	a	a
Y7	a	a
Y8	a	a
Y9	a	a
Y10	a	a
Y11	a	a
Y12	a	a
Y13	a	a
Y14	a	a
Y15	a	a
Y16	a	a
Y17	b	a
Y18	b	b

Physical (Three Segment)



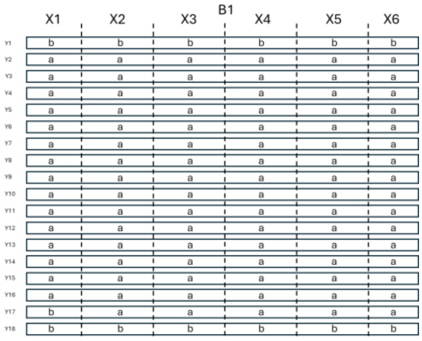
	X1	X2	X3
Y1	b	b	b
Y2	a	a	a
Y3	a	a	a
Y4	a	a	a
Y5	a	a	a
Y6	a	a	a
Y7	a	a	a
Y8	a	a	a
Y9	a	a	a
Y10	a	a	a
Y11	a	a	a
Y12	a	a	a
Y13	a	a	a
Y14	a	a	a
Y15	a	a	a
Y16	a	a	a
Y17	b	a	a
Y18	b	b	b

Physical (Four Segment)



	X1	X2	X3	X4
Y1	b	b	b	b
Y2	a	a	a	a
Y3	a	a	a	a
Y4	a	a	a	a
Y5	a	a	a	a
Y6	a	a	a	a
Y7	a	a	a	a
Y8	a	a	a	a
Y9	a	a	a	a
Y10	a	a	a	a
Y11	a	a	a	a
Y12	a	a	a	a
Y13	a	a	a	a
Y14	a	a	a	a
Y15	a	a	a	a
Y16	a	a	a	a
Y17	b	a	a	a
Y18	b	b	b	b

Physical (Six Segment)



	X1	X2	X3	X4	X5	X6
Y1	b	b	b	b	b	b
Y2	a	a	a	a	a	a
Y3	a	a	a	a	a	a
Y4	a	a	a	a	a	a
Y5	a	a	a	a	a	a
Y6	a	a	a	a	a	a
Y7	a	a	a	a	a	a
Y8	a	a	a	a	a	a
Y9	a	a	a	a	a	a
Y10	a	a	a	a	a	a
Y11	a	a	a	a	a	a
Y12	a	a	a	a	a	a
Y13	a	a	a	a	a	a
Y14	a	a	a	a	a	a
Y15	a	a	a	a	a	a
Y16	a	a	a	a	a	a
Y17	b	a	a	a	a	a
Y18	b	b	b	b	b	b