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SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING

INVENTORY AND INSPECTION GUIDELINE FOR RAILWAY BRIDGES

A Thesis in Railway Engineering

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A Thesis

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The undersigned have examined the thesis entitled '**Inventory and Inspection Guideline for Railway Bridges**' presented by **Addisu Desalegne**, a candidate for the degree of **Master of Science** and hereby certify that it is worthy of acceptance.

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UNDERTAKING

I certify that research work titled “Inventory and Inspection Guideline for Railway Bridges” is my own work. The work has not been presented elsewhere for assessment. Where material has been used from other sources it has been properly acknowledged / referred.

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ABSTRACT

Due to the substantial role of bridges in transportation network and in accordance with the limited fund for bridge management, remedial strategies have to be prioritized. A conservative bridge assessment will result in unnecessary actions, such as costly bridge strengthening or repairs. On the other hand, negligence and delayed action of bridge maintenance may lead to heavy future costs or degraded assets. The accuracy of decisions developed by any manager or bridge engineer relies on the accuracy of the bridge assessment which emanates from well-established bridge Inventory and Inspection.

A high degree of accurate Bridge Database is only maintained if the bridge Inventory and Inspection is carried out using well-established guideline. If bridge Inventory and Inspection tasks are not performed for all bridges without having a well-established guideline, frequent collapse would occur at the same time in many parts of the county and would provoke social and political chaos. As a new government corporate the Ethiopian Railway Corporation needs to start the bridge asset management by inventory and inspecting of its new assets. To perform this, sustainability of well-established bridge Inventory and Inspection guideline should be established. Therefore; the main goal of this research is study preparation of Inventory and Inspection Guideline for Railway Bridges in Ethiopia by adapting the practice in similar sources. In this research Inventory and Inspection Guideline for Ethiopian railway bridges is studied from the experience of different countries, bridges administration authorities ERA, AACRA, manuals and others relevant sources, and a seed for Rail Bridge Management System established.

Keywords: Railway Bridges, Inventory, Inspection, Guideline

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LIST OF ABBREVIATIONS

AALRT	Addis Ababa Light Rail Transit
ERC	Ethiopian Railway Corporation
RC	Reinforced Concrete
PSC	Pre stressed Concrete
AREMA	American Railway Engineering & Maintenance of way Association
AASHTO	American Association of State Highway and Transportation Office
FCM	Fracture critical member
NBIS	National Bridge Inspection Standard
RBI	Risk-Based Inspection
OF	Occurrence Factors
CF	Consequence Factors
HPC	High Performance Concrete
ADT	Average Daily Traffic
ADTT	Average Daily Train Traffic
AADT	Annual Average Daily Traffic
GPS	Global Positioning System
FRA	Federal Railroad Administration
DOT	Department of Transportation
ERA	Ethiopian Roads Authority
AACRA	Addis Ababa City Roads Authority
BMS	Bridge Management System
ERA-BMS	Ethiopian Roads Authority - Bridge Management System
ID	Identification Number
BSc	Bachelor of Science
MSc	Master of Science
ORA	Oromiya Roads Authority
C/C	Center to Center

1. INTRODUCTION

1.1 Background

The Ethiopian Railways Corporation has identified eight railway corridors for study, design and subsequent implementation. In the coming few years, the Ethiopian railway network will contains more than 5000 km of national standard gauge railway line [1]. Some of the projects are currently providing services such as the Addis Ababa Light Rail. These railroad networks include crossing over rivers, structures and valleys which include bridges and culverts. Bridges are the main connective parts and provide smooth riding over obstacles.

The Railway Bridges cost enormously and occupy strategic importance in the movement of goods, passengers and defense materials all over the country. Bridges are expensive and key elements of the Railway network because of their strategic location and of the dangerous consequences when they fail or when their capacity is impaired [2].

It is certain that the volume of railway bridge stock will increase in the country as the railroad networks enter in to operations. This situation shows that, it is not possible to leave this huge volume of asset without regular Inventory, inspection and systematic database management. When these railway networks enter in to operation, the owner, the Ethiopian Railway Corporation, is expected to administer this large number of bridges. As a new company, the Railway Corporation needs to start the bridge management by inventory and inspecting of its new assets.

Currently, in our country, bridge inventory and inspection does not get attention as their construction. When the constructions completed and enter in to services, the major task will be asset management. One of the assets management in this network is Bridge Asset Management. Special attention should be provided for bridge assets because, their construction cost is high and if the bridges collapsed with poor bridge asset management, the result would be very severe. So, proper and well organized bridge asset management must be established. To achieve this bridges inventory and inspection are important activities to be performed. Without inventory and inspection of the bridges, bridge asset management is a dream. To do this sustainability of well-established bridge Inventory and Inspection guideline should be established.

The Bridge Inventory and Inspection System data is dynamic, reflecting changes due to: Bridge Replacement Projects, Bridge Rehabilitation Projects, Cyclical Maintenance, Bridge Inspections, and Administrative Modifications. Data is entered and processed by various methods. The Bridge Inspection Program is the major source of updates to the bridge data [3, 4].

All bridges within the Inventory shall be inspected to evaluate the condition of the structure due to the effects of corrosion, collision, or alterations due to improvement programs that are not reflected on previous inspection reports. All changes need to be thoroughly documented and reported in the inspections so that their effect can be analyzed in subsequent load ratings [5].

Inspection is to be done to identify and measure the deterioration which may be caused by applied loads and other factors i.e. dead load, live load, and wind load and physical and chemical influenous of climate apart of the natural or accidental calamities. Inspection can also need to identify any built - in - imperfections and also help to increase the useful life of bridges [2].

By doing so the data recorded for each bridge will assist future database users in assess the safety and condition of bridges, data and information to all the activities of Bridge Management Cycle, the effect of any changes in traffic loads and to determine the strength or load carrying capacity , any potential trouble spots, hard facts on the results of new constructions and measures, budget for repair and maintenance, on the behavior of repair and new strengthening techniques and in other research and engineering activities.

During operation bridges cannot keep good conditions forever. Bridges start deteriorating soon after their completion because of the actions of weather, traffic and other various causes. If the bridge inventory and inspections are not carried out for all of the bridges, they would collapse frequently across the county and would invite social and political troubles without doubt. One bridge collapse can cause casualties and require considerable amount of money and time to reconstruct the new bridge [6].

It is important to understand that a bridge consists of several members and elements that have different durability in nature due to the difference of materials, locations, and sensitivities

against weather and loads. This indicates that in order to keep the appropriate functions of bridges expected in design, appropriate inventory and inspection is essential in response to the actual deteriorations.

If the bridge inventory and inspections are not properly carried out for all of the bridges, the following could be happened:

- Collapse
- Loss of life
- Loss of considerable amount of money to reconstruct and termination of train services.
- Takes much time to reconstruct
- Social & political trouble
- Repair works will be more expensive
- Fragmental issues in bridge management
- A conservative bridge assessment will result in unnecessary actions
- Negligence and delayed action of bridge maintenance may lead to heavy future cost
- Difficult to make critical decisions such as closure and reconstruction of the bridges

In our country, there is no prepared inventory and inspection guideline for railroad bridges. As a new government corporate, the Ethiopian Railway Corporation needs to start the bridge asset management by inventory and inspecting of its new assets. To perform this, sustainability of well-established bridge Inventory and Inspection guideline should be established. Some of the railway projects are proving services like Addis Ababa light rail transit. Therefore, it is the exact time to prepare the inventory and inspection guideline for railroad bridges.

Hence, discussion made to reach the conclusion by analyzing and comparing all the questionnaire survey, good practices and standards. Data collection and analysis is the core of the whole thesis study, where all data needed for the research are collected and analyzed. Finally based on all data gathered giving conclusion and recommendation on preparation of Inventory and Inspection Guideline for Railway Bridges.

1.2 Objective and Scope of the Study

1.2.1 Objective of the Study

General Objective

The main objective of the study is to prepare guideline for inventory and inspection of railway bridges to ensure that the bridge continues to perform its function under acceptable conditions of safety and with minimized cost of maintenance which intern is the seed for Rail Bridge Management System.

Specific Objectives

The specific objectives of the research address the following points:

- Inventory and inspection formats
- Types and frequency of inspection
- Procedures and Facilities for Inventory and Inspection
- Safety Measures during Inventory and Inspection
- Suggested Personnel Requirements
- Reporting inventory and inspection findings
- On the basis of which forward recommendations, which would help the preparation of Inventory and Inspection Guideline for Railway.

1.2.2 Scope of the Study

In Ethiopia, the railway construction sector is growing very fast. It is believed that in the coming few years the Ethiopian railway network will contain more than 5000 km of national standard gauge railway line. Among the many elements in this network Bridges are the expensive and key elements of the Railway network because of their strategic location and of the dangerous consequences when they fail or when their capacity is impaired. Therefore, in this study only railway bridges are considered where, culverts are not accounted.

1.3 Presentation of the Thesis

The content of this study includes five chapters,

- Chapter 1 includes introduction to Railway Bridges Inventory and Inspection, Specific and General Objectives and Presentation of the study.
- Chapter 2 addresses literature review related with the study work.
- Chapter 3: include Data Collection, Sampling and Analysis, Description of Respondents, findings of Survey Data from AALRT and ERC, findings of Survey Data from Professionals in Highway Bridge Engineers and findings of Survey Data from Ethio-Djibouti Railway Company.
- Chapter 4: describes Guideline for Inventory and Inspection, Inventory Format, Types and Frequency of Bridge Inspection, Measuring Bridge Defects / Damages, Inspection Formats, Determination of Railway Bridge Conditions, Procedures of Railway Bridge Inventory and Inspection, Photograph guidelines, Facilities for Railway Bridge Inventory and Inspection, Types of bridge inspection Investigation, Safety Measures during Inventory and Inspection, Suggested Personnel Requirements and finally how to Reporting Inventory and Inspection Findings.
- Chapter 5: summarizes the whole works in this study through conclusion, recommendation and future research options.

2. LITERATURE REVIEW

2.1 Concept of Railway Bridges Inventory and Inspection

2.1.1 Railway Bridge Inventory

Bridge Inventory is a database, which is compiled by Bridge owners, with information on all railway bridges. The data is often used to analyze bridges and judge their conditions.

The bridge inventory is developed to have a unified database for bridges including identification information, bridge types and specifications, operational conditions, and bridge data including geometric data, functional description, etc. [7].

Table 2-1: Data Inventory Components [4, 7]

Bridge Inventory Component	Contents
Bridge Identification Information	○ Bridge Identification Number ○ Bridge location / Coordinate ○ Bridge spatial location ○ Identification of routes under and/or above the structure ○ Owner
Bridge Type and Specifications	○ General Type of Main Span ○ General Type of Approach Span ○ Number and Length of Main Spans ○ Number and Length of Approach Spans ○ Length of Maximum Span ○ Total Length of Bridge ○ Out to Out Width ○ Deck, deck surface, and other bridge component ○ Abutment Type (Beginning & End) ○ Abutment Wing wall Type (Beginning & End) ○ Abutment Footing Type (Beginning & End) ○ Abutment Pile Type (Beginning & End) ○ Abutment Height (Beginning & End) ○ Materials ○ Skew Angle
Operation Conditions	○ Construction year, rehabilitation year ○ Type of services and traffic carried over and/or under the structure ○ Design Load ○ Number of the lanes over and/or under the bridges, average daily traffic, average daily truck traffic and information regarding to bypasses, detours, etc.
Bridge Data	○ Geometry, inspection data, ratings and appraisal results
Remark on others not included in the reference	o Pier Type (Beginning & End) o Pier Wing wall Type (Beginning & End) o Pier Footing Type (Beginning & End) o Pier Pile Type (Beginning & End) o Pier Height (Beginning & End) Girder Depth Concrete and Steel Grade

2.1.2 Railway Bridge Inspection

Bridge inspection is an action to assess correctly the bridge conditions in a standardized manner and is the most important element in the Bridge Management Cycle that is the systematic maintenance process of inspection, assessment, selection of measures, prioritization and repair to keep bridges in satisfactory levels. The purpose of bridge inspection is not simply to collect the latest information about the present bridge conditions but, more importantly, it should be understood that the inspection is to provide essential information for Bridge Management Cycle. The railroad administration sometimes must take the critical decisions such as closure and reconstruction of the bridge based on the inspection results [6].

Inspection lays the foundation of the entire maintenance programme.

The purpose of inspection of a bridge can be identified as follows; [2]:

- To provide assurance that the bridge is structurally safe and fit for its designed use. This relates to the gradual deterioration of the bridge with time or to an accidental occurrence such as earthquake, overloading, derailment etc.
- To identify actual and potential sources of trouble at the earliest possible stage.
- To record systematically and periodically the state of the structure. This enables one to know the time when defects occurred and to identify any significant structural changes.
- To provide feed-back of information to designers and custodians of bridges on those features which are likely to give maintenance problems and to which necessary attention is best given during design and construction stages ; and
- To provide necessary information on which decision will be made for carrying out maintenance repairs, strengthening or replacement of the structure.

2.2 Railway Bridges Inventory Formats

This is a format in which inventory findings of railway bridges recorded. This format provides information about general bridge information, location of bridges, types of bridges and dimension of bridge components. This format makes the bridge inventory process more accurate and the information submitted to the Bridge Database maintains a high degree of accuracy.

Sample format of Inventory in **Appendix D**-where:

1. Format adopted by New York State Department of Transportation
2. Format adopted by Ethiopian Roads Authority

As shown in the appendix, the Bridge Inventory Formats includes the General Information of the bridge includes Dimensions of the bridge, River condition, Topography, Alignment, Load capacity, Construction year and cost, Contractor, consultant, Safety load limit sign and Detour possibility. Furthermore, it includes super structure, substructure and foundation, components and ancillaries.

2.3 Railway Bridges Inspection

There are different types of bridge inspection performed in terms of purposes, frequencies and method of investigation. The types and frequency of bridge inspection is also not the same with different organization of the same country. Each bridge owner has its own criteria in order to decide the types and frequency of inspection. Among the criteria's to decide on the types and frequency of inspections are method of investigations / inspection, availability of inspection personnel's, budget, types and conditions of the bridges. The following table shows types and frequency of bridge inspection looks like from country to country and different authorities.

Table 2-2: Types and Frequency of Bridge Inspection

Manual / Owner	Classification of Inspection	Purpose	Frequency	Method
AREMA [8]	Periodic	To identify changes in the condition of the bridge compared with previous inspections	annually	Observations of all components of the bridge.
	Special	To obtain detailed information that includes photographs, verification of bridge dimensions and member sizes, and accurate and member-specific data of any deterioration.		hands-on inspections and includes laboratory testing
	Emergency	To evaluate damage to a bridge caused by flood, fires, earthquake, derailment, collision or other unusual occurrences.	As neded	
Main Roads Western Australia [9]	Level 1 – Routine Visual Inspections	to check on the overall safety and performance of the structure and the identification of any major accident damage or incident	annually	visual inspections

		and any obvious failure of structural components.		
	Level 2 – Detailed Visual Inspections, Condition Assessments	Quantitative data on structural components are collected for use in engineering analyses and deterioration models	5 year cycle	detailed visual inspection where all components are inspected closely (within 1.0 m)
	Level 3 – Special Inspections and Investigations	to concerns over the structure's safety, condition, and load capacity or for structures subject to complex associated repair, strengthening or widening works	As needed	
Connecticut Department of Transportation Office of Rail [10]	Routine Inspections	to identify any critical problems or deficiencies	every two years	
	Verification Inspections	to confirm the condition of the bridge components, as identified in the previous Routine or In-depth Inspection Report	every two years	
	In-depth Inspections	to assess and record the physical condition of the bridge, to ascertain that the bridge is functioning as shown on the original plans and to ensure that the bridge is adequate to safely carry the intended loads	every 10 years	"hands-on" examination of all exposed parts of a bridge, non-destructive testing and laboratory testing
	Special Inspections	to monitor a particular known or suspected deficiency, following any incident that may have an effect on the structural integrity of a bridge		
	Underwater Inspections	to monitor known or suspected deficiencies such as scour, pile deterioration or foundation undermining, and to determine the impacts of flood conditions.		involve visually and tactually inspecting all the exposed underwater components of the structure
Government of India Ministry of Railways [2]	General/ Routine Inspection		annually	visual inspection
	Detailed inspection		once in five year	thorough examination of each and every component of the Bridge and its super structure is carried out with the help of equipment covering all points against a prepared checklist

	Special inspection	bridge which needs an inspection due to some extraordinary reasons i.e. distressed and early steel bridges, bridge damaged due to accidents or natural calamities, bridge to be undergone heavy repairs etc	As needed	
AASHTO [11]	Initial (Inventory)	The first inspection of a bridge as it becomes a part of a bridge file. But the elements of an initial inspection may also apply when there has been a change in configuration of the structure (e.g., widening, lengthening, supplemental bents, etc.) or a change in bridge ownership.	As needed	
	Routine (Periodic)	to determine the physical and functional condition of the bridge	not to exceed 2 years	observations and/or measurements needed
	Damage inspection	to assess structural damage resulting from environmental factors or human actions	unscheduled inspection	
	In-Depth	to identify any deficiencies	National Bridge Inspection Standard (NBIS), establish criteria to determine the level and frequency of this type of inspection	is a close-up, inspection of one or more members above or below the water level and Nondestructive field tests may need
	Fracture Critical	is performed within arm's length of steel members in tension, or with a tension element, who failure would probably cause a portion of or the entire bridge to collapse	not to exceed 2 years	visual methods and nondestructive testing
	Underwater	inspection of the underwater portion of a bridge substructure and the surrounding channel, which cannot be inspected visually at low water by wading or probing	not to exceed 60 months	diving or other appropriate procedures
	Special (Interim)	to monitor a particular known or suspected deficiency, such as foundation settlement or scour, fatigue damage, or the public's use of a load posted bridge	National Bridge Inspection Standard (NBIS), establish criteria to determine the level and frequency of this type of inspection	
U.S. Department of	Routine inspections		not to exceed 2 years	

Transportation [12]	Underwater inspections		not to exceed 60 months	
	Fracture critical member (FCM) inspections		not to exceed 2 years	
	Damage, in-depth, and special inspections			
U.S federal highway administration [13]	Initial Inspection	the first inspection of a bridge as it becomes a part of a bridge file	within 60 days after construction is complete	
	Routine	to obtain inventory information and quickly look for deficiencies		
	In-Depth			
	Interim Inspection	to have deficiencies or other problems that require more frequent inspection than the typical inspection frequency		
	Damage Inspection	traffic impact on the post, an over height hit of the truss or sign panels		
Massachusetts Bay Transportation Authority Railroad Operations Directorate [14]	Periodic Inspections		1-year intervals	
	Underwater Inspections		5-year intervals	
	Emergency Inspections		as needed	
	Fracture Critical Inspections		minimum 2-year intervals	

2.3.2 Inspecting Railway Bridges

Deck Inspection

The three main categories of railroad bridge decks are [10]:

A. **Ballasted Deck:** On a ballast deck bridge, the rail is fastened to standard track ties resting in a bed of ballast that is confined by a ballast pan or tub which is then connected to the bridge superstructure.

Figure 2-1: Ballasted Deck

B. **Open Deck:** An open deck is a bridge deck where the rail and tie plate is fastened to timber bridge ties that rest directly on the main structure of the bridge. Open decks are typically used on steel or timber spans. Open deck concrete bridges are uncommon.

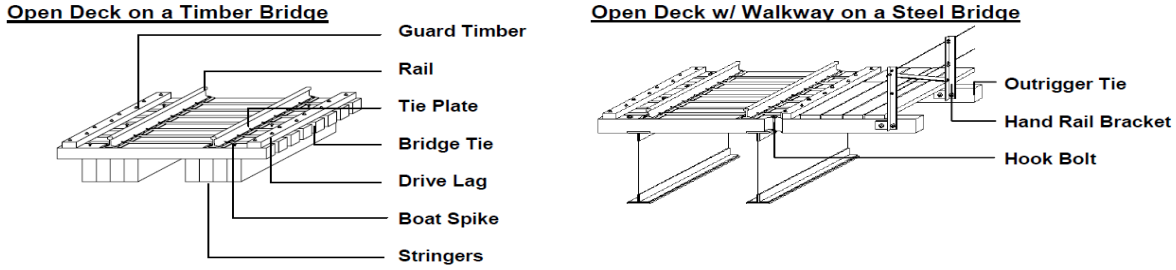


Figure 2-2: Deck Open

C. **Direct Fixation Deck:** On a direct fixation deck, the rails are anchored directly to the main structure of the bridge.

Figure 2-3: Direct Fixation Deck

The Railway Bridge Elements plays a crucial role in supporting the train. Subjected to the direct action of the train, Railroad Bridges often develop defects and require maintenance. For these reasons it is important that every railroad bridge be thoroughly inspected on a regular basis. The following table shows the Type and Extent of Inspection on Railway Bridges.

Table 2-3: Type and Extent of Inspection on Ballasted Deck, Open Deck, Direct Fixation and Ballast Retainer [10]

Type and Extent of Inspection activity	Main Railway Bridge Category or Components				
	Ballasted Deck	**Open Deck**	**Direct Fixation Deck**	**Ballast Retainer**	**Remark**
Unusual Condition / Defect Inspection	Wear on the rail, spikes, tie plate, drive lags, guards, ties, fouled ballast, excessive ballast, ballast leaks and evidence of poor drainage	Wear on the rail, spikes, tie plate, drive lags, guards, ties, pumping of the track and/or bridge ties	Wear on the rail, spikes, tie plate, drive lags, guards and ties	Deterioration on Concrete, Steel and Stone Masonry, and water leakage	Visible defects on top surface and underside of the bridge elements with adequate light shall be noted
Documentation for Routine Inspection	Size and Location of cracks, spalls, delaminations, etc.	location of the pumping track and/or bridge ties and location of line and surface defects	Deck notes should be organized in a "span by span"	size and relative location on the bridge	Note size, location and orientation of defects like crack, spalling, etc.
In-depth Inspection	underside of the deck, depth of the ballast and cracking, scaling, wetness or staining shall be sounded with a hammer	General condition of tie, split ties, broken ties or decayed ties, derailment or fire damage shifted or skewed ties and Horizontal shear cracks	General condition of tie, split ties, broken ties or decayed ties	Any Deterioration on Ballast Retainer and Overloading	Close visual inspection to the whole bridge elements to identify bridge defects
Documentation for In-depth Inspection	Sketches sizes and types of deteriorations, average depth of ballast and photograph of the deck	location of loose and missing rail components	Sketches sizes and types of deteriorations	Sketches sizes and types of deteriorations and photograph	Note and Sketch any deterioration or deficiency and Representative photographs of specific problem

Table 2-4: Type and Extent of Inspection on Deck Joint and Drainage System [10]

Type and Extent of Inspection activity	Main Railway Bridge Category or Components		
	Deck Joint	**Drainage System**	**Remark**
Unusual Condition / Defect Inspection	Deterioration due to cracks, excessive vibration, loose or missing mortar, loose, damaged or broken components, vertical displacement, excessive movement and deflection	Corrosion, impacted rust, section loss, cracks, dings, gouges, impact damage, missing components, sediment and ability to effectively channel runoff	Visible defects on top surface and underside of the bridge elements with adequate light shall be noted
Documentation for Routine Inspection	Note any deterioration, concrete losses, locations and lengths of all cracks	Note any deterioration or deficiency and drainage system's effectiveness as a whole	Note size, location and orientation of defects like crack, spalling, etc.
In-depth Inspection	Check the deck joint not securely anchored to the superstructure or deck (deteriorated concrete)	hands-on access shall be provided to the entire drainage system	Close visual inspection to the whole bridge elements to identify bridge defects
Documentation for In-depth Inspection	Structural condition of whole Deck Joint and quality photograph	Note any deterioration or deficiency and drainage system's effectiveness as a whole	Note and Sketch any deterioration or deficiency and Representative photographs of specific problem

Table 2-5: Type and Extent of Inspection on Super Structure and Sub Structure [10]

Type and Extent of Inspection activity	Main Railway Bridge Category or Components					
	Super Structure			Sub Structure		Remark
	Bearings	Reinforced Concrete Slab	Pre stressed Concrete	Concrete Substructures	Masonry Substructures	
Unusual Condition / Defect Inspection	Debris and corrosion, anchor bolts, pumping under live load, cracked welds	cracks, delamination, scaling, wetness shall be tapped with a hammer to determine soundness and tension or shear cracks	cracks on bearing areas and anchorages, scale, cracks with efflorescence, wetness, rust staining, interiors of box beams/girders and tapped with a hammer to detect patterns of delamination	bearing seat areas, pier caps in areas of high tension or shear stresses, cracking, scaling, wetness, Spalling, tipping or settlement, scour	spalled, disintegrated, weathered, displaced, missing or cracked stones, missing joint mortar, efflorescence, vegetation growth, deformations, tilting, settlement, rotation, scour	Visible defects on top surface and underside of the bridge elements with adequate light shall be noted
Documentation for Routine Inspection	Sketch special or unusual problems, measure and note pumping, weld cracks and bearing joints	sketch that shows the size, location and orientation of deficiencies like crack, spalling, etc.	sketch that shows the size, location and orientation of deficiencies like flexure and shear cracks, spalling, etc.	A narrative description of defects and Sketches	Note size, location and orientation of deteriorations, scour and impact damage	Note size, location and orientation of defects like crack, spalling, etc.
In-depth Inspection	tapped anchor bolts with a hammer to check firmly anchored to the substructure and pumping under live load	hands-on access shall be provided to the entire slab underside and cracking, scaling, wetness or staining shall be sounded with a hammer	hands-on access shall be provided to the entire superstructure and cracking, scaling, wetness or staining shall be sounded with a hammer	hands-on access shall be provided to the entire substructure and cracking, scaling, wetness or staining shall be sounded with a hammer	hands-on access shall be provided to the entire substructure and plumb bob to check the vertical alignment	Close visual inspection to the whole bridge elements to identify bridge defects
Documentation for In-depth Inspection	complete bearing measurement forms and note and measure pumping under live load	sketch that shows the size, location and orientation of deficiencies like crack, spalling, etc. and photograph of the defects	sketch that shows the size, location and orientation of deficiencies like crack, spalling, etc. and photograph of the defects	Detailed sketches and Representative photographs of specific problem	Detailed sketches and Representative photographs of specific problem	Note and Sketch any deterioration or deficiency and Representative photographs of specific problem

2.3.3 Frequency of Bridge Inspection

Frequency of inspection is dependent on the type of structure, its location, its age, its condition and load rating of the bridge. Structures constructed of materials known to deteriorate at a relatively rapid rate in unfavorable conditions require more frequent inspections to ensure the health and safety are maintained [9, 14].

The factors in determining inspection frequencies include: [10]

1. Time since last inspection.
2. Risk management of known defects.
3. Following natural disasters, viz. floods, bushfires, and earthquakes.
4. Strategic importance of a route or bridge.
5. Notification from the public.
6. Availability of special equipment and/or resources.
7. Future live load increase

The frequency of inspections can be determined either on a time basis, or by the condition of the bridge and the liability associated with the rate of deterioration arising from the above factors [10].

Increased Inspection Interval: Each qualifying railroad structure on inactive or abandoned railroad lines may be inspected by qualified railroad bridge inspectors at regular intervals of 24 months [10].

Decreased Inspection Interval: A railroad bridge shall be inspected more when such inspection frequency is necessary considering conditions noted on prior inspections, the type and configuration of the bridge, or the weight and frequency of traffic carried on the bridge [10].

2.3.4 A guideline for Determination of Bridge Inspection Interval Using Reliability-Based Bridge Inspection Practices

Reliability-Based Bridge Inspection describes a methodology for developing Risk-Based Inspection (RBI) practices for highway bridges. The goal of the methodology is to improve the safety and reliability of bridges by focusing inspection efforts where most needed and optimizing the use of resources. The guideline provides a framework and procedures for developing suitable inspection strategies based on a rational engineering assessment of inspection needs. The methodology considers the structure type, age, condition, importance, environment, loading, prior problems, and other characteristics that contribute to the reliability and durability of highway bridges [15].

This is done through a relatively simple process that consists of three primary steps: [15]

Step 1: What can go wrong, and how likely is it? Identify possible damage modes for the elements of a selected bridge type. Considering design, loading, and condition characteristics (attributes), categorize the likelihood of serious damage occurring into one of four occurrence factors (OFs) ranging from remote (very unlikely) to high (very likely).

Step 2: What are the consequences? Assess the consequences, in terms of safety and serviceability, assuming the given damage modes occur. Categorize the potential consequences into one of four consequence factors (CFs) ranging from low (minor effect on serviceability) through severe (i.e., bridge collapse, loss of life).

Step 3: Determine the inspection interval and scope. Use a simple 4 × 4 matrix to prioritize inspection needs and assign an inspection interval for the bridge based on the results of Steps 1 and 2. Damage modes that are likely to occur and have high consequences are prioritized over damage modes that are unlikely to occur or are of little consequence in terms of safety. A Reliability-Based Bridge procedure is developed based on the assessment of typical damage modes for the bridges being assessed.

The uniform approach provides a single maximum inspection interval for most bridges, regardless of the bridge age, design, or environment. However, such a uniform inspection interval does not consider explicitly the likelihood of failure based on bridge condition, design, or operating environment, or the potential consequences of a failure. A uniform inspection interval does not recognize that a newly constructed bridge with improved durability characteristics and a few years of exposure to the service environment may be much less likely to develop serious damage over a given time interval than an older bridge that has been exposed to the service environment for many years. Bridges that are in benign, arid operating environments are inspected at the same interval as bridges in aggressive marine environments, where significant damage from corrosion may develop much more rapidly [15].

A risk-based approach has been adopted in many industries as a tool for inspection planning, to focus attention on the component or machine that represents the greatest "risk." Risk is defined as the product of the probability of an event and the associated consequences. Probability is the likelihood of an adverse event or failure occurring during a given time period. Consequence is a measure of the impact of the event occurring, which may be measured in terms of economic, social, safety, or environmental impacts.

Risk = Probability × Consequence

An important concept in risk analysis is to understand that high likelihood does not necessarily mean high risk, if the consequences are small. Similarly, high consequence does not necessarily mean high risk, if the likelihood is small. The level of risk can only be determined once both of these variables are assessed [15].

The setting of inspection frequencies or intervals is not a rigid process, such as is the case for uniform or calendar-based inspection frequencies. Rather, it is a process that evolves and changes over the life of a component such that inspection frequencies change as risk increases (or decreases).

Guideline for Determining the Inspection Interval

Inspection intervals are determined based on the reliability analysis using a simple four by four matrix as shown below, which illustrates a risk matrix for a typical highway bridge. Engineering judgment is required for establishing the specific divisions applied to the risk matrix; the divisions are generally applied to ensure that the likelihood of damage remains low during the interval between inspections, such that there are multiple inspections conducted before there is a high likelihood of failure occurring. When consequences are relatively high, should the failure occur, the interval is further reduced to provide an extra margin of safety [15].

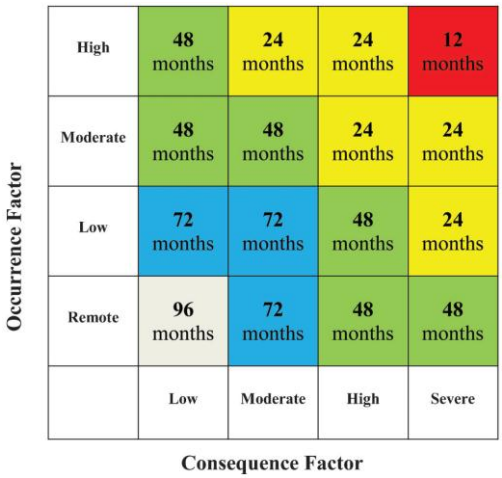


Figure 2-4 Risk Matrix [16]

2.3.5 Inspection Format

The bridge inspection format is essential in order to handle a complete record of the bridge inspection and to employ a uniform bridge inspection reporting system. It is made to include mainly Railway Bridge elements, types of Defects, Rating of defects and Inspectors Recommendation

Furthermore, it is necessary for establishing maintenance priorities, replacement priorities, and in determining structure capacities.

Sample format adopted by different country including the one used by Ethio-Djibouti Railway Company is attached in **Appendix E.**

The bridge inspection format that was used by the Ethio-Djibouti Railway Company was mostly for Metallic Bridges. However, currently most of the railway bridge types are prestresed concrete bridges.

Major Bridge Components

In general terms, the major components of track carrying structure are very similar to their non-railway counterparts [17].

Table 2-6: Major Bridge Components

Major Bridge Components			
Substructure	Piling	bearing/friction pile	
		sheet pile	
	mat footing		
	spread footings		
	piers		
	abutments	wing	
		"U"	
		"T."	
Superstructure	Bridge Deck	Open deck	Bridge Floors
			Drainage
			Anchorage of Bridge Ties
		Ballasted Decks	Ballast
			Drainage

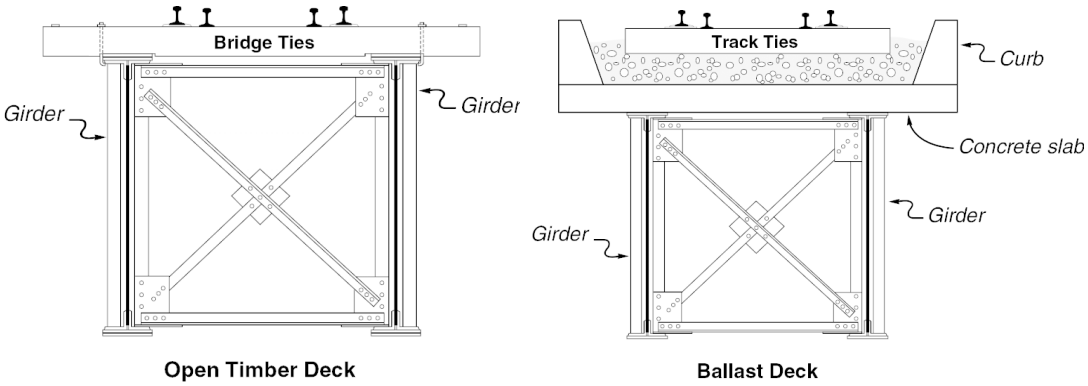


Figure 2-5: Open Deck Structure and Ballast Decked Bridge [17]

Figure 2-6: Bridge Types [17]

Bridge Types	
Steel Bridges	Deck Plate Girder
Concrete Bridges	Arches
	Rigid-Frame Bridge
	Slab Bridges
	Concrete Girders

Figure 2-7: Deck Plate Girder [17]

2.4 Procedures of Railway Bridge Inventory and Inspection

2.4.1 Procedures of Inventory and Inspection

Planning and scheduling

Proper planning and scheduling of bridge inspection activities promotes: [10]

- Effective and efficient completion of the bridge inventory and inspection task
- Proper utilization of Limited manpower and budgetary

The followings activities are included in Planning and scheduling: [10]

A/ Document Review: This includes the following with respect to review the available information

- "As-Built" bridge plans and shop drawings, where available
- Maintenance and Repair Records/Correspondence
- Previous inspection reports
- Correspondence pertinent to any required work or work completed

B/ Pre-Inspection: visits to the bridge site for determining access requirements (or impediments to normal access), establishing the need for and type of any maintenance and protection of traffic required and observing the overall condition of the bridge to gage time requirements. The visits may be to see that there is no construction activity in the area that might interfere with access or maintenance and protection of traffic patterns, and to make the inspection team aware of more than one structure in a close proximity that may require similar special access equipment.

C/ Coordination of Access and Equipment Needs

The above two steps enable the inspector's review the situation, the equipment and access requirements necessary for to proper performing the inspection.

A letter shall be sent to different concerned body to facilitate the inspection process.

D/ Weather Considerations

Considering the possible weather conditions when scheduling inspections can permit a more thorough and comfortable inspection.

The following sequence of inspection is suggested for most bridges: [10]

1. Inspect the deck from the top.
2. Inspect the bridge approaches.
3. Inspect the underside of the deck.
4. Inspect the bearings.
5. Inspect the beams/superstructure.
6. Inspect the abutments and wings.
7. Inspect the piers.
8. Inspect the waterway.

2.4.2 Photograph guidelines

Photographs are to be taken at the time of the bridge inspection. They are used to provide site information of the bridge and to support comments on the condition of the bridge reported by the Inspector. Further photographs of the bridge parts like new repairs and major defects also needed [10].

General Photograph Requirements for Bridges [10]:

- View from the approach at Abutment 1 end and Abutment 2 end
- View of the bridge from the left hand side and right hand side
- Overall view of Abutment 1and Abutment 2
- Overall view of Overall view of a typical pier
- Overall view of the underside of a typical span

2.5 Facilities Railway Bridge Inventory and Inspection

A significant portion of the railroad bridge inspections are performed without train loads, since many of the railroad bridges within the railroad network are not otherwise accessible. In these cases, railroads perform their inspections by using high-rail cars. High-rail cars are vehicles equipped to ride both on highway and rail environments by switching their trucking equipment. High-rail cars allow access to bridges. Once bridge inspectors reach bridges via high-rail cards, railroads make use of small cranes to bring bridge inspectors under the bridge

deck and other areas that need to be inspected [18]. Other facilities used for inspection includes those shown in the table of **Appendix F.**

2.6 Types of Bridge Inspection Investigation

There are two types of investigations: [19]

A/ On-site Investigations

Visual Inspection

A visual inspection is the first used to determine the general condition of the structures, identify areas of distress, likely sources of problems and identify the visible defects. This will confirm that the test plan is suitable and critical areas have been included. All visible defects such as concrete cracking, apparent delamination, concrete spalling, exposed corroding reinforcement etc. need to be recorded with standardized notation. Reinforcement size, type, orientation, corrosion state and loss of cross section area are to be recorded at all exposed reinforcement locations. Photographs of visible defects and worse shall be taken to document the in situ condition.

In Situ Testing

Surface tests – such as rebound hammer, half-cell potentials, resistivity, ultrasonic pulse velocity, corrosion rate measurements etc.

Material sampling – methods for taking samples of materials from the structure to determine composition and properties of the material or the presence of deleterious substances, such as chlorides in concrete. Some sampling may be taken from inside core holes.

Intrusive testing – such as drilling holes or concrete breakout to determine the condition inside the structure that is not revealed by visual inspection, such as the corrosion state of steel reinforcement, the condition of post-tensioning tendons or the interior of box girder sections.

B/ Laboratory Investigation

Laboratory investigation becomes essential where the available information is insufficient to complete a non-destructive evaluation with confidence. In conjunction with the onsite investigation program, laboratory investigation may be required to understand potential causes of deterioration.

Figure 2-8: Example of taking a core sample [19]

Figure 2-9: Example of collecting powder sample for laboratory analysis [19]

A photographic record at sample locations must be taken. The samples obtained should be labeled, their orientation clearly marked and wrapped in cling film or stored in airtight sample bags as soon as practicable after sampling.

Once samples of concrete have been obtained, whether by coring, drilling, or other means, they should be examined in a qualified laboratory. In general, the examination will include one or more of the following examinations:

- Petrographic examination (cores or fragments only)
- Chemical analysis (chloride content, cement content, original water cement ratio, sulfate content etc.)
- Physical analysis (compressive strength, density etc.)

2.7 Safety Measures during Inventory and Inspection

At some bridge sites it may be difficult to find a safe parking location especially at bridge sites on railroads where train speed is high or where there is insufficient room within the track side. In some situations, parking at the bridge site may not be safe and alternate parking locations and walking to the bridge site may be needed [10].

Access to bridge components for inspection via bridge abutment embankments can potentially pose a safety risk to the Inspector due to steep embankments and loose surface material. The Inspector should take note of this information prior to arriving on site and make suitable arrangements for safe access as required [10].

Any work performed for the inspection of bridges or structures within the vicinity of electrified corridor(s) may require electrified catenary to be de-energized. The requirements for de-energizing sections of corridor shall be coordinated with Electricians [14].

While Inspecting Bridges one should adopt certain safety measures which are listed below: [2]

- Wear suitable dress so that loose end don't get caught ; too-tight a dress may hamper your free movements
- If you normally wear glasses for improving your eye sight, wear them when climbing up or down sub-structures & super structures.
- Keep clothing & shoe free from grease and steel stars or nail etc. which causes slipping.
- Scaffolding or platforms should be free from grease or other slippery substances.
- Scaffolding and working platforms should be adequate strength and be secured against slipping or overturning.
- No shortcut at any cost. Vigil over passing trains
- Keep your trolley and other equipment's properly so that they should not infringe the track.
- Say no to liquor or any other sedative medicine.
- Follow all operating rules and follow the guide lines while inspecting under any caution order/ block (power/ traffic or both)
- Be careful while walking moving through footpaths/ any other members.
- No chit, chatting and fun etc. while on Inspection.

2.8 Suggested Personnel Requirements

There are three categories of personnel associated with bridge inspection: [14]

1. **Program Manager:** one responsible and in charge of all inspection teams and procedures
2. **Team Leader:** one, who is in charge of planning, performing, and reporting the inspection
3. **Inspectors:** one who assist the Team Leader in the inspection. The inspector is a technician who should be able to reach all parts of the bridge to be inspected, detect indications of deterioration or other problems on the bridge, and accurately record and report them.

On the other hand, the following alternative Personnel for Railway Bridge Inventory and Inspection may be employed [10].

1/ Railroad Bridge Engineer, whose responsibility includes:

- Determine the forces and stresses in railroad bridges and bridge components;
- Prescribe safe loading conditions for railroad bridges;
- Prescribe inspection and maintenance procedures for railroad bridges;
- Design repairs and modifications to railroad bridges.

2/ Railroad Bridge Inspector, whose responsibilities includes:

- To view, measure, report and record the condition of a railroad bridge and its individual components; and
- To Authorize or restrict the operation of railroad traffic over a bridge according to its immediate condition or state of repair.

3/ Railroad Bridge Supervisor, whose responsibilities includes:

- Supervises the modification or repair of a railroad bridge in conformance with common or particular specifications, plans and instructions applicable to the work to be performed; and
- Authorize or restrict the operation of railroad traffic over a bridge according to its immediate condition or state of repair.

All personnel expected to be familiar with the Inspection Hand Book or Manual [10].

2.9 Reporting Inventory and Inspection Findings

The bridge inspection report is a complete record of the bridge inspection. It contains the field notes and sketches completed during the inspection, completed standard inspection forms, supporting photographs, an executive summary, and possibly a Railroad Bridge Maintenance Memorandum, if required. Inspection reports may contain bridge plans, if they were not previously on file, or rehabilitation plans, if work has been done on the bridge [10].

All bridge inspections shall be documented in standardized reports, the formats of which will be provided by the Authority. Inspection reports shall include at a minimum, standardized inspection forms with numerical condition ratings and photographic documentation [14].

All inspection reports shall include the following standard sketches as a minimum, followed by sketches of noted deficiencies [14]:

- Plan
- Elevation
- Cross Section
- Pier Elevation

The Inspection Report should consist of the following general sections: [19]

- Executive Summary
- Introduction,
- Detailed investigation results.
- discussion of investigation results,
- Summary of current condition
- Conclusions,
- Recommended remedial actions for defects identified
- Recommendations on further testing and schedule, if required.

When a critical defect affecting the safety of the bridge structure or the safety of the traveling public is found during an inspection, it is imperative that the Bridge Engineer is responsible to inform the situation immediately [10].

The following information should be noted for reporting critical defects [10]:

- Structure Number
- Town
- Route Number/Road Name
- Type of Bridge
- Type of Defect Encountered
- Location of Defect (Span, Girder, Stringer…)
- Other Pertinent Information

2.10 Ethiopian Experience of Bridge Inventory and Inspection

2.10.1 Ethiopian Roads Authority

Route classification and functional description

The Ethiopian Roads Authority classifies the road networks in to five functional classes based on average annual daily traffic and their economic importance. Each of these functional roads numbered with a letter in the prefix. The following table shows road functional classification, numbering and AADT [20].

Table 2-7: Ethiopian Roads Authority Main Roads, Road Functional Classification and Numbering [20]

Road Functional Classification	Numbering	AADT	Remark
Trunk Roads (Class I)	numbered with an "A" prefix	≥1000	Roads terminating at international boundaries are linked with Addis Ababa
Link Roads (Class II)	numbered with a "B" prefix	50-10,000	Centers of national or international importance linked between each other
Main Access Roads (Class III)	Numbered with a "C" prefix.	30-1,000	Centers of provincial importance must be linked between each other
Collector Roads (Class IV)	numbered with a "D" prefix	25-400	Roads linking locally important centers to each other, to a more important center
Feeder Roads (Class V)	numbered with an "E" prefix	0-100	Any road link to a minor center such as market and local locations

The classification and description of sample existing trunk, link, feeder, collector and main access roads within the country, includes road name, type of road and road numbering. For example:

Table 2-8: Ethiopian Roads Authority Main Road and Route Numbering

Main Road	Main Road Name	Route No	Route Name	Road Segment	Road classification
A1	Addis - Djibouti	A1-1	Addis -Modjo	Addis -Modjo	Trunk Road
A2	Addis - Axum	A2-1	Addis - Debreberhan	Addis - Aleltu	Trunk Road
B102	Alaba-Wulbareg	B102-4	Alaba-Wulbareg	Saja - Asendabo	Feeder Road

Assigning ID for the bridges

The above classification and numbering of the roads make the road networks easily identified and laid a base for inventory and road asset administration. Along this entire road networks, there are a number of structures like bridges and culverts.

According to Ethiopian Roads Authority, 2013 bridge database there are more than 3,777 bridges and more than 25,690 culverts along all the way in the road networks [21].

ERA has a procedure in assigning ID for the bridges. As shown in the table above, each main road have its own ID number and each of this main roads further divided in to road section. Then a unique ID is provided for these sections. In the same way each of this road sections

subdivided in to road segment and ID is provided for these segments. Finally, a unique ID is assigned for each bridge in these road segments. For example:-

The main road along Addis Ababa – Djibouti numbered with A1. This main road further divided in to a road sections like Modjo section. Again this road section is further divided in to segments like Addis Ababa – Modjo and numbered with A1-1. Then bridges existed in this road segments are numbered according to their order arrangement. Based on this procedure each bridge in the entire road network has a unique ID number as shown in the table below.

Table 2-9: ERA, Assigning ID number for bridges [21]

Main Road	Main Road Name	Route No	Route Name	Road Segment	Bridge No
A1	Addis - Djibouti	A1-1	Addis -Modjo	Addis -Modjo	A1-1-001
A1	Addis - Djibouti	A1-1	Addis -Modjo	Addis -Modjo	A1-1-002

2.10.2 The Ethio-Djibouti Railway Company

The Franco Ethiopian Railway from 1900 to 1980

Numerous structures, with a total length of 6080 m, ensure the passage of water under the tracks.

On line A from **Djibouti to Dire-Dawa**: **[22]**

667 structures, culverts and box culverts from 1m to 30m of which the principal ones shown in the table below:

Table 2-10: Principal Bridges On line A from Djibouti to Dire-Dawa, Ethio-Djibouti Railway Line [22]

Bridge Name	Span Composition	Chainage
The bridge Chébélé	9m x 16m H 20m	PK 22
The bridge Hol - Hol	8m x 16m H 28m	PK 52
The Tunnel Pass Harr	170m	PK 189
The bridge Andobet	45m	PK 233
The Mello bridge	12m + (2 x 31,5m)	PK 246
Oued H'raoua	6m x 12m	PK 264
Oued EDGI	2 X 12m	
Oued Tchéfalé	6 X 12m	PK 290
The Laga Haré		PK 291

On line B from **Dire-Dawa to Addis-Ababa:**

1252 structures, culverts and box culverts of which the principal ones shown in the table below are: [22]

Table 2-11: Principal Bridges On line B from Djibouti to Dire-Dawa, Addis Ababa Railway Line [22]

Bridge Nmae	Span Composition	Chainage
The bridge Laga Bore	22m+38+22m H 32m	KM 73
The bridge Oulakiki		
Bridge Karaba		
The bridge of the Awash	42m+57+42m H 60m	KM 102
The bridge of Bola		KM 401
Bridge Modjo		KM 408
Bridge Doukham		KM 441
The bridge Goguetcha		
The bridge of the Akaki		

The Djibouti-Ethiopian railway after 1980

Numerous structures, totaling 6080m, ensure the passage of water under the tracks. These structures were maintained, and improved, for more than 75 years with the help of French representatives, reflecting the volume of traffic and weight of locomotives [22].

The end of the reign of the Emperor of Ethiopia in 1974 and, from 1977 onwards, Djibouti's Independence, the Somali-Ethiopian conflict in the Ogaden and the consequences of the then political regime, all contributed through lack of care to the deterioration of these important installations where sample damages along the railway line route on Bridges shown below: [22]

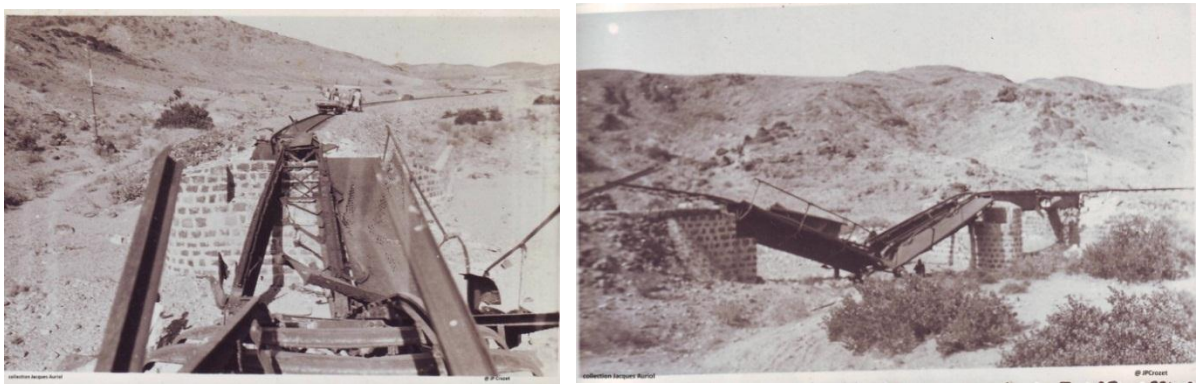


Figure 2-10: Sabotage Region Dasbiou 1941 [22]

Figure 2-11: Sabotage Region Daouenle 1941 [22]

Figure 2-12: Egion Goudeto 1970 [22]

Figure 2-13: Awash Bridge Destroyed By Italian during the Invasion 1941 [22]

Figure 2-14: Laga Oda Bridge [22]

As the railway only had one track it was necessary, in case of derailment or accident, to free the line as soon as possible in order to restore service. This was a priority and a real achievement.

The maintenance team did not have heavy lifting cranes. The whole operation was achieved using jacks for lifting or shifting. Trucks on their side were unloaded and reloaded by employees responsible for the maintenance of the line. Depending on the circumstances, an emergency track could be laid out before lifting the wreck. This would allow the repositioning of the trucks and locomotives before leading them back on to the main track. Accidents and derailments required great effort. An emergency train loaded with lifting gear, camping equipment, food and water was always at the ready [22].

Table 2-12: The famous Bridge Failures during the operation of the Ethio-Djibouti railway line

It No.	Name of the River	Name of the Bridge	Reason for Bridge Failure
1	Harawa	Harawa	Explosive
2	Awash	Awash	Oversize of the train load
3	Hol Hol	Hol Hol	Accident
4	Afdem	Afdem	Explosive

Figure 2-15: Train Accident due to Bridge Abutment scoured 1935 [22]

Figure 2-16: Bridge Failure due to scoured abutment 1955 [22]

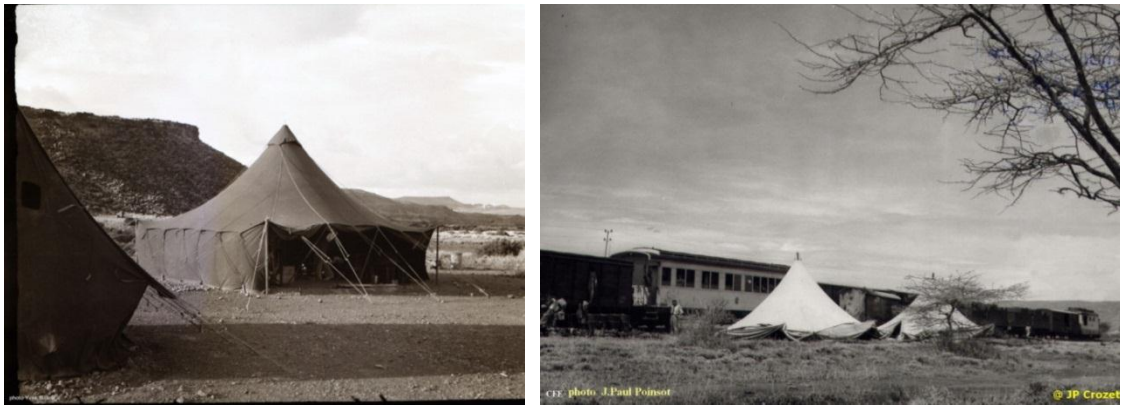


Figure 2-17: Site Camp for Emergency Team 1951 [22]

Figure 2-18: Sabotage Italian Army 1941, Awash River Bridge [22]

Figure 2-19: Oued Andobed Bridge 1950 [22]

The main reason for termination of operation of the old Ethio-Djibouti Railway Line was poor management, unable to upgrade or modernize the company or railway line due to budget constraints, frequent accidents and bankruptcy.

2.10.3 Ethiopian Railway Corporation

The following railway track defects were detected during visual inspection along Adama - Awash section. This inspection includes railway track over the bridges [23].

Table 2-13: Detected railway track defects along Adama - Awash section

Railway Track Components	Defects
Rail	Corrosion
	Wavy profile / Zigzag line
	No Guardrail at the curve section
	Very wide or Very narrow Expansion Joint
Ballast, Sleeper, Fastening system	Vibration
	Poorly tamped ballast
	Inadequate ballast width
	Inadequate ballast depth
	Ballast size (too much larger than the standard size)
	Poor Ballast quality
	Unnecessary materials within the ballast
	Suspended Sleepers on the ballast
	Bolt Missing
	Loose bolt
Draining system	Not align with the runoff alignment

Recommendations given by ERC in the above findings:

- The rail shall be tested and approved according to the contract document and based on international standard before operation.
- The bolts which are loosen and lost shall be checked and fixed properly.
- Longitudinal irregularities shall be avoided since they may be a cause for derailment
- Training should be given to the society to protect the track structure from damage which could be caused by lack of knowledge.
- Ballast shall be delivered after proper inspection and tests has been performed to control the strength, gradation, size, flakiness and other qualitative properties.
- Ballast shall be filled and tamped properly according to the design document or international standard
- There shall be no dust, silt, debris or other materials which can deteriorate the quality of rail, sleeper, ballast, sub ballast and other structures of the track.
- Great attention should be given to Hydrological problems, since it may damage the bridge and the track structure completely. Bridges and related drainage problems shall be designed based on detailed study of the hydrology and soil condition. The construction should also be with skilled and careful manpower.

2.10.4 Addis Ababa Light Rail Transit

Addis Ababa Light Rail Transit Track Procedures:

Track failure: it mainly refers to [24]

- The rail is broken or seriously damaged
- The frog is seriously damaged
- The expansion track and joint splints are all broken

Breakoff of steel rail: It is deemed that the steel rail breaks off under any of the following circumstances: [25]

- The complete cross section of the steel rail breaks into two parts at least;
- The crack goes through the whole section of the railhead;
- The crack goes through the whole section of the rail bottom;
- A part more than 50mm long and 10mm deep drops from the top of the steel rail.

The track's static check cycle: The whole line will be checked monthly.

The track's routing inspection cycle: shall be conducted no less than once every day.

The main track: check shall be conducted once every year.

Inspection for key sections shall be strengthened

1) Tour diagram or inspection plan shall be prepared
2) The tour diagram stipulates commencement date and dead track, inspection time, tour route, start-stop sections, key inspection parts, requirements of shift change and other contents.
3) The inspectors shall possess high responsibility, enjoy good health and certain professional skills
4) The inspectors be familiar with relevant rules and regulations and track business

Main contents for inspection of track equipment over the bridges

1) Rail inspection: inspect whether the marked damage is aggravated and determine the rail according to damage standards**.**

2) Inspection of clamp plate and bolt: inspect deformation, flaw, breaking and rail gap of the clamp plate (including emergency restore device) according to standards; inspect looseness and defect of track bolt, fastener bolt and gasket.

3) Turnout inspection: inspect crack falling, matching and empty sling of switch rail; inspect frog and guard rail; inspect connecting parts.

4) Inspection of rail overlapping device: inspect crack falling, matching and empty sling of switch rail and stock rail; inspect connecting parts; record the expansion amount.

5) Inspection of subgrade ballast bed: inspect sinking, falling and collapse of subgrade ballast bed; inspect damage of sleepers; inspect flooding of subgrade and bed ponding; inspect whether the drainage ditch is silted up and whether there is crack and damage in the ballast bed.

6) **For clearance limit obstacles:** move away the clearance limit obstacles and do small repair in inspection.
7) **Ballast bed and concrete short sleepers:** inspect whether there is serious cracking and deformation in ballast bead and concrete short sleepers.
8) Inspect whether the track sign is firm.

Regulations and notes for inspection tour

- Application of start and end shall be
- The inspector shall walk in the road center and pay attention to holes in viaduct section.
- The inspection speed shall not exceed 3km/h.

Inspection of rail damage over the Bridge

The regulations of the tolerance management values of static geometric dimension of track (V≤80㎞/h) are as per the following table.

Table 2-14: the tolerance management values of static geometric dimension of track [25]

Items		Acceptance of operation (㎜)		Regular maintenance (㎜)		Urgent repair (㎜)	
		Main track and auxiliary track	Yard track	Main track and auxiliary track	Yard track	Main track and auxiliary track	Yard track
Gauge		+6 -2	+6 -2	+7 -4	+9 -4	+9 -4	+10 -4
Level		4	5	6	8	10	11
High-low		4	5	6	8	10	11
Direction		4	5	6	8	10	11
Twist of track (twisted)	Easement curve	4	5	5	7	7	8
	Straight line and circular curve	4	5	6	8	9	10

Table 2-15: AALRT Rail Defect Standard [25]

Defect items	Defect degree		Remarks
	Light defect	Heavy defect	
	υmax≤80km／h	υmax≤80km／h	
Head abrasion	See rail head abrasion standard	See rail head abrasion standard	
Peeling or chip falling at the rail end or top	Length of more than 15mm and depth of more than 4mm	Length of more than 30mm and depth of more than 8mm	
Rail surface scratch	Depth of more than 1mm	Depth of more than 2mm	
Low rail joint	More than 3mm	More than 3.5mm	Measure the vector at the lowest place with a 1m straight ruler, including the rail end and top crush and abrasion
Wave abrasion	Trough of more than 0.5mm		
Rail surface crack		Yes	Including bolt hole crack, horizontal crack at railhead lower jaw (rust), horizontal crack at rail web, longitudinal crack of railhead, rail base crack (excluding scale cracks on the rail top surface or near surface caused by wheel-rail contact fatigue)
Rail internal crack		Yes	Including core flaw (black, white core), longitudinal crack of rail, etc.
Rail deformation		Yes	Railhead expansion, rail web warp or bumps which are determined as a hidden internal crack
Rail corrosion		After rust removal, rail base thickness is less than 5mm or rail web thickness is less than 8mm	

Table 2-16: Railhead Abrasion Light Defect Standard [25]

(kg/m) Rail	Total abrasion (mm)		Vertical abrasion (mm)		Side abrasion (mm)	
	Main track and testing track	Other tacks	Main track and testing track	Other tacks	Main track and testing track	Other tacks
50	12	14	8	9	12	14

Note: ①Total abrasion= Vertical abrasion +1／2 Side abrasion

②Vertical abrasion is measured at the place 1／3 of railhead width (from the standard working edge).

③Side abrasion is measured at the place 16mm below rail tread (according to the standard surface).

Table 2-17: Railhead Abrasion Heavy Defect Standard [25]

(kg/m) Rail	Vertical abrasion (mm)	Side abrasion (mm)
	υmax≤80km/h Main track and yard track	υmax≤80km/h Main track and yard track
50	10	17

3. DATA COLLECTION, SAMPLING AND ANALYSIS

3.1 Introduction

The research methodology gives justification in the choice of methodology used to achieve the objective of the study which is specified at the beginning. Further, it gives research population, sample size and data collection methods and tools.

3.2 Research Design

The strategy followed in this research was first started with problem identification which has been done through unstructured literature review, archival study and informal discussion with colleagues and professionals in the sector and then the research design was formulated. Then data and information sources were determined based on the formulated research design.

On the basis of the data and information sources the research instruments were decided and available documentary sources relevant to the research were reviewed. The review includes books, manuals and journal.

Finally, after an in-depth review of literature, a questionnaire was designed and distributed to Addis Ababa Light Rail Transit, Ethiopian Railway Corporation, Ethio-Djibouti Railway Company and Professionals in Bridge Asset Management to get their opinion based on their experience. Upon obtaining the desired data, checking and sorting of data has been done. The data's were then analyzed for extracting the information obtained through the overall research work. This was followed by thorough discussions in order to draw a conclusion and to forward recommendations based on the findings of the study.

Sample Questioners for ERC and AALRT, Ethio-Djibouti Railway Company and Bridge Professionals is attached in **Appendix A, Appendix B** and **Appendix C** respectively.

A descriptive and exploratory survey design was used in this study. It was attempted to collect data from the relevant population (Railway Authorities who administer bridges and Professional in Bridge Asset Management) to evaluate their perception on the issues of Bridge Inventory and Inspection.

3.3 Source of Data and Research Instrument

Multiple evidences approach was used for data collection. These are questionnaire survey, analyzing different documents and manuals and experience.

Questionnaire survey was selected as the research instrument owing to its suitability to the level of information required, unavailable information related with railway bridge inventory and inspection data and cost and time limitations.

Three types of questioners were prepared. The 1st questioner was prepared for Ethiopian Railway Corporations and AALRT in order to assess what the Railway Bridge Inventory and Inspection Practices looks like and to understand how these companies plan to administer their railway bridges. The 2nd questioner was prepared for the Ethio-Djibouti Railway Company in order to understand what the Railway Bridge Inventory and Inspection practices were look like. And the 3rd questioner was prepared for Professionals in Highway Bridges Asset Management in order to share their experience in Bridge Inventory and Inspection.

The questionnaire form, which was accompanied by a covering letter, consists of different parts. Basically, the questions were structured or closed type questions. But, in view of obtaining as much information as possible, participants were encouraged to give additional information or comments on the open spaces provided under each question.

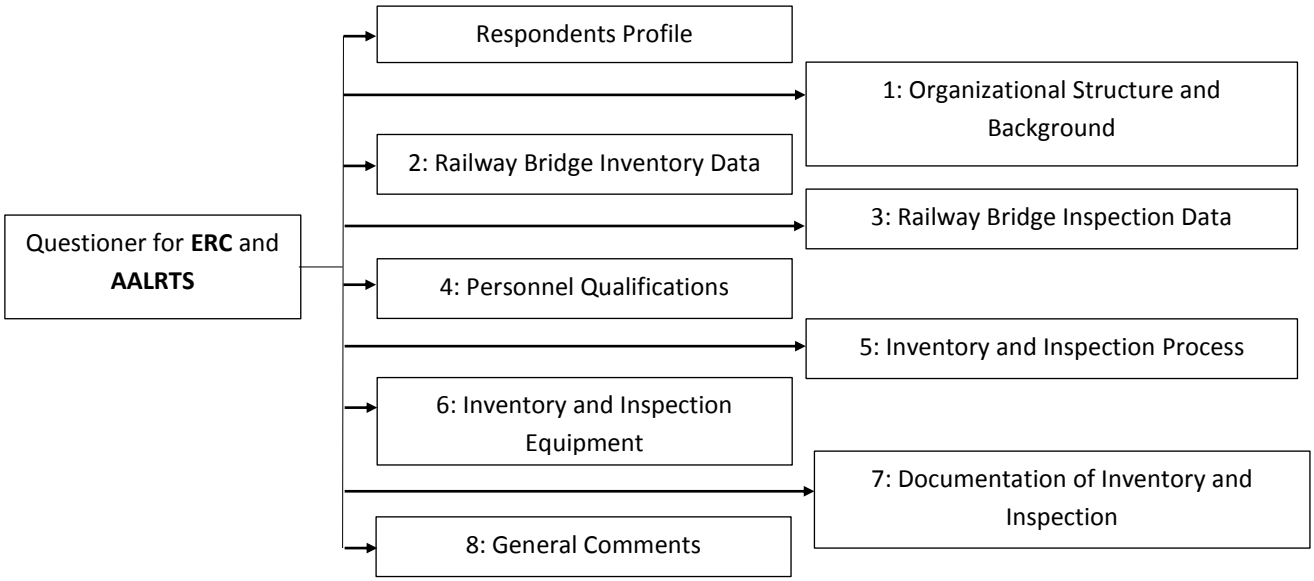


Figure 3-1: Questioner for ERC and AALRTS

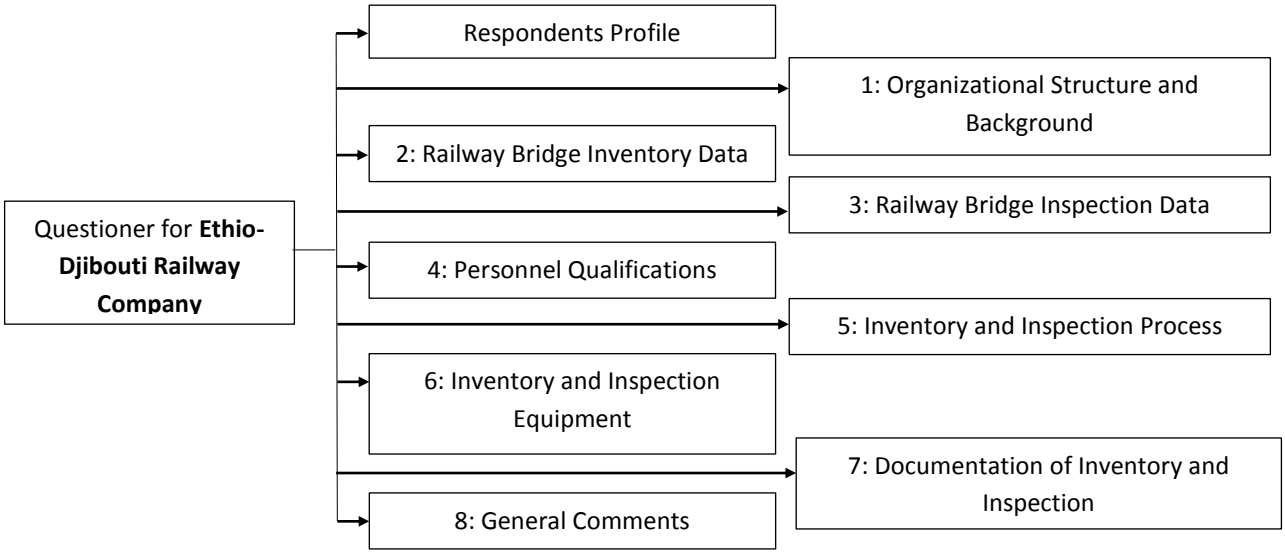


Figure 3-2: Questioner for Ethio-Djibouti Railway Company

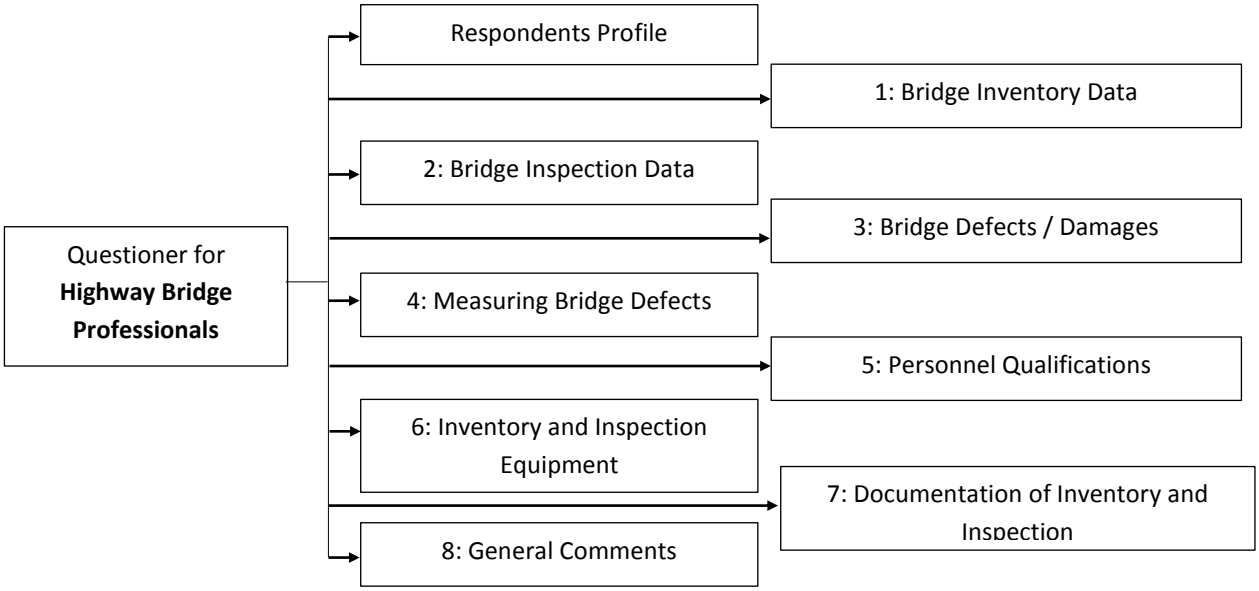


Figure 3-3: Questioner for Highway Bridge Professionals

3.4 Method of Data Analysis

The analysis was done using Microsoft Excel and the responses assigned to each questions by the respondents were entered and consequently the responses from ERC, AALRTS, Ethio-Djibouti Railway Company and Highway Bridge Professional questionnaires were subjected to statistical analysis for further insight. The statistical techniques which are grouped under various headings were then employed to analyze the data collected from the survey.

Frequency tables and descriptive statistics were constructed to display results with respect to each of the questions.

3.5 Research Population and Sampling

This part aims to display the results of this study. The quantitative research findings are outlined in table, different types of charts and text form. Each result was discussed in short however certain results were followed by a more in-depth discussion.

Three different questionnaires were administered, one for ERC and AALRT, one for Ethio-Djibouti Railway Company and the other for Professionals in Bridge Inventory and Inspection. The questionnaires comprised of eight parts with different details for each groups of respondent as the study aimed to do a thorough research investigation.

The total number of distributed questionnaire in this study consisted of fifty eight but collected responses were only fifty one. Out of the returned questionnaires, fourteen were rejected for the analysis due to many unreplied questions observed in the questionnaire contained therein.

Table 3-1: Response rate of the questionnaire

No	Stakeholder	Questionnaire distributed		Returned questionnaire		Failed questionnaire		Analyzed questionnaire	
		No.	(%)	No.	(%)	No.	(%)	No.	(%)
1	ERC and AALRT	15	100.00	15	100.00	4	26.67	11	73.33
2	Ethio-Djibouti Railway Company	7	100.00	5	71.43	3	42.86	2	28.57
3	Highway Bridge Professionals	36	100.00	31	86.11	7	19.44	24	66.67
Total		**58**	**100.00**	**51**	**87.93**	**14**	**24.14**	**37**	**63.79**

3.6 Description of Respondents

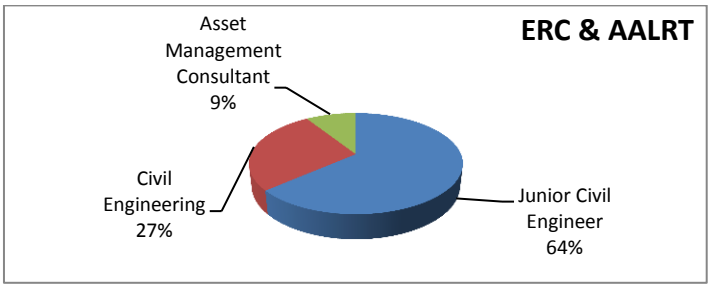
3.6.1 Classification of Organization

Table 3-2: Classification of companies

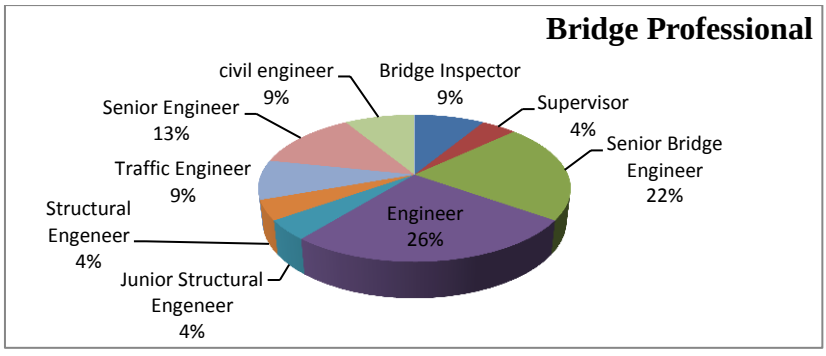
No	Stakeholder		Analyzed questionnaire	
			No.	(%)
1	Ethiopian Railway Corporation		10	27.03
	Addis Ababa Light Rail Transit		1	2.70
2	Ethio-Djibouti Railway Company		2	5.41
3	Bridge Professional	Ethiopian Roads Authority	8	21.62
4		Oromiya Roads Authority	3	8.11
5		Addis Ababa City Roads Authority	3	8.11
6		South Roads Authority	1	2.70
7		Hitcon Engineering PLC	3	8.11
8		Omega Consulting Engineers	3	8.11
9		Others Companies and Professionals	3	8.11
Total			**37**	**100**

3.6.2 Respondents' Position

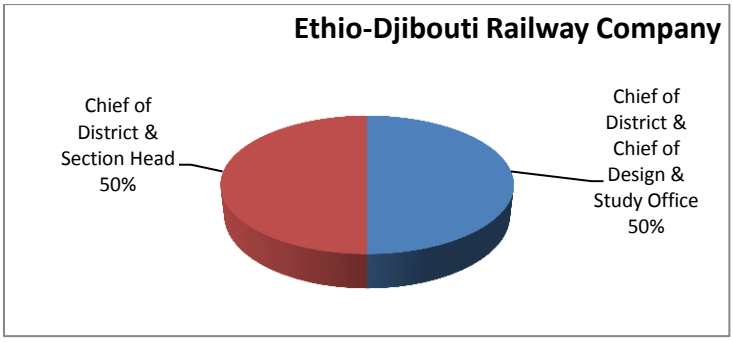
The distribution of respondents' position of ERC and AALRT is shown below:



The distribution of respondents' position of Highway Bridge Professionals:



The distribution of respondents' position of Ethio-Djibouti Railway Company:



3.6.3 Respondents Educational Background

The table below illustrates the level of educational of respondents.

Table 3-3: Educational background of respondents

Educational background	ERC & AALRT		Ethio-Djibouti Railway		Professionals in Bridge Asset Management		Total	
	No.	(%)	No.	(%)	No.	(%)	No.	(%)
PHd.	0	0.00	0	0.00	0	0.00	0	0.00
MSc	8	72.73	2	100.00	6	25.00	16	43.24
BSc	3	27.27	0	0.00	16	66.67	19	51.35
Diploma	0	0.00	0	0.00	2	8.33	2	5.40
Certificate	0	0.00	0	0.00	0	0.00	0	0.00
Total	**11**	**100.00**	**2**	**100.00**	**24**	**100.00**	**37**	**100**

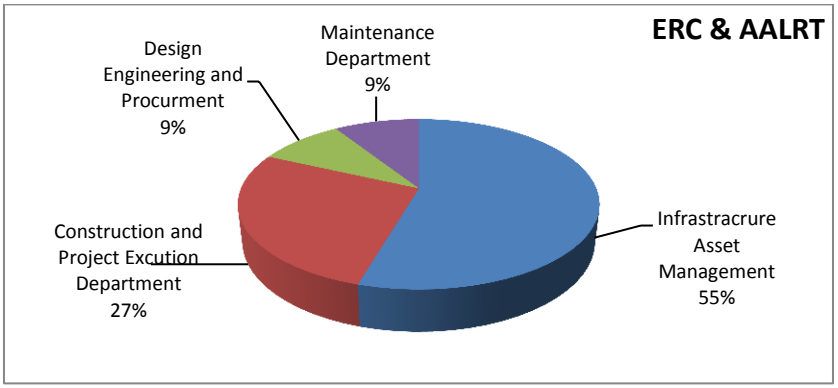
3.6.4 Respondents Experience

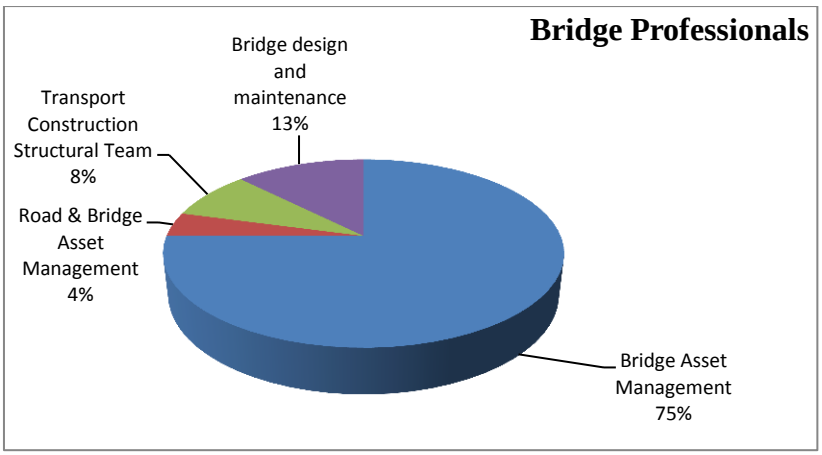
The table below shows the respondent's years of experience.

Table 3-4: Respondent's experience

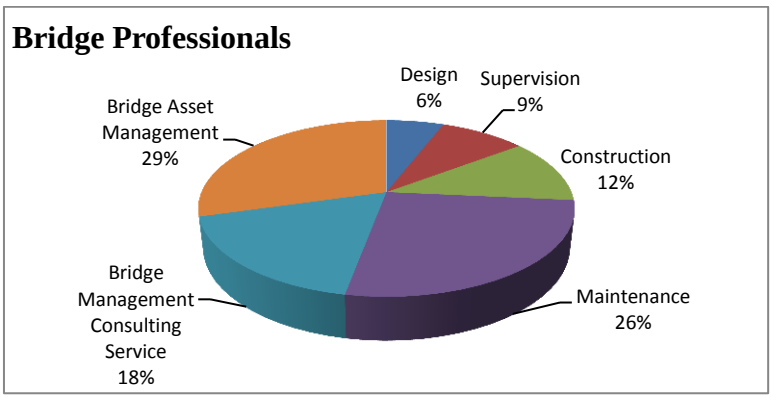
Experience in years		ERC & AALRT		Ethio-Djibouti Railway		Professionals in Bridge Asset Management		Total	
		No.	(%)	No.	(%)	No.	(%)	No.	(%)
Experience in the Structure / Bridge Engineering	< 2	2	18.18	0	0.00	2	8.33	4	10.81
	3-5	8	72.73	0	0.00	8	33.33	16	43.24
	6-10	0	0.00	0	0.00	10	41.67	10	27.03
	11-15	0	0.00	0	0.00	3	12.50	3	8.11
	> 15	1	9.09	2	100.00	1	4.17	4	10.81
	Total	11	100.00	2	100.00	24	100.00	37	100.00

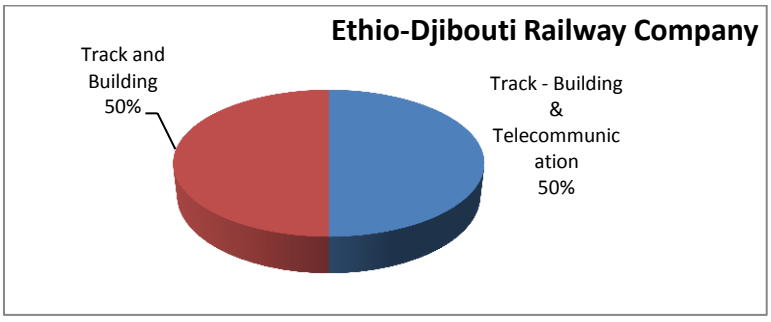
3.6.5 Work Unit / Department of respondents





Work Experience as a Structural/Bridge Engineer





Since the result of the questionnaires is very vast only findings form the questioner is presented and the details are attached in the annex.

3.7 Survey Data from AALRT and ERC, Ethio-Djibouti Railway Company and Bridge Professionals

The response summary to questioner is provided in table below:

3.7.1 Organizational Structure and Background

Table 3-5: Response Summary of Organizational Structure and Background of AALRT and ERC, Ethio-Djibouti Railway Company and Bridge Professionals

Item Description	Response Summary			
	AALRT and ERC	Ethio-Djibouti Railway Company	Bridge Professionals	Remark
Which railway lines are owned by ERC?	All railway lines	–	–	(-) means Questions was not referred
Who was the owner of the old railway line along Addis Ababa-Dewele?	–	the government of Ethiopian and Djibouti	–	(-) means Questions was not referred
Who is responsible for inventory and inspection of Bridges in AALRT?	No clear answer	the government of Ethiopian and Djibouti	–	(-) means Questions was not referred
Who is responsible for inventory and inspection of bridges along all Federal Railway Networks?	ERC	–	–	(-) means Questions was not referred
Is there any Guideline, Organizational regulation and central database related to inventory & inspection of railway bridges in Ethiopia?	No Guideline, Organizational regulation and central database	No Guideline & Bridge Central Database and there was Organizational regulation	–	(-) means Questions was not referred
What is the total numbers of railway bridges registered in your organization?	Unknown	Unknown	–	(-) means Questions was not referred
How old are your bridges?	< 5 years old	Most of the bridges are > 60 years old	–	(-) means Questions was not referred
What are the types of railway bridges in your organizations?	precast box girder, cast in place box girder, precast i – beam, precast integral beam and slab, precast box units, cast in place slab panels, rigid frame bridge, box girder, deck girder, cast in place box units, slab and I-beam	Steel concrete composite bridges like box girder and steel beam & concrete deck and steel bridges like I-beam and truss bridges	types of railway bridges encountered by bridge professionals are Precast box girder, Cast in place box girder, Precast i – beam, Cast in place i – beam, Cast in place integral beam and slab, Precast box units, Cast in place box units, Cast in place t – beams, Precast slab panels, Box girder, Deck girder, Arch, Precast box units, Cast in place box units, Slab, Steel beams & concrete deck, I-beam and Truss	

3.7.2 Railway Bridge Inventory Data

Table 3-6: Response Summary of Railway Bridge Inventory Data

Item Description	Response Summary			
	AALRT and ERC	Ethio-Djibouti Railway Company	Bridge Professionals	Remark
What is the name to identify Addis Ababa-Djibouti railway track?	Addis Ababa-Djibouti Railway Line	Addis Ababa – Djibouti Railway Line	–	(-) means Questions was not referred
How do you divide the railway truck?	by stations distribution	by sections like Dawanle-Djibouti (S11)	–	(-) means Questions was not referred
Is there any bridge Identification Numbering System?	No	–	–	(-) means Questions was not referred
Distance in km of Bridge location is measured from_____	from starting of stations for example, the starting point for the national railway line can be Sebeta Station	Djibouti (0+00)		
What would be the span length appropriate to be bridge in bridge asset management in your opinion?	–	–	≥ 6.0m	(-) means Questions was not referred

3.7.3 Railway Bridge Inspection Data

Table 3-7: Response summary of Railway Bridge Inspection

Item Description	Response Summary						
	AALRT and ERC		Ethio-Djibouti Railway Company		Bridge Professionals		Remark
Factors attribute to the deteriorate condition of bridges over time?	–		–		live load, flood, earthquake, collision, environmental factors and fatigue		(-) means Questions was not referred
What different types of inspections are performed on railway bridges?	Initial, Regular, Detail and Emergency		Visual, Detail and Emergency		Initial, Regular, Detail and Emergency		
Frequency / interval of railway bridge inspection considering available budget and inspection personnel's	initial inspection	3 months after the bridge owner handover the bridge asset	NA		initial inspection	3 months after the bridge owner handover the bridge asset	
	regular inspection	every year	regular inspection	every day	regular inspection	every year	
	major inspection	every five year	major inspection	every 6 months	major inspection	every five year	
	emergency inspection	immediately up on occurrence	emergency inspection	immediately up on occurrence	emergency inspection	immediately up on occurrence	
Do you perform hands-on/close-up inspection?	Yes		No		–		(-) means Questions was not referred
Methods of Highway Bridge Inspection Practice in Ethiopia	–		–		based on visual observation		(-) means Questions was not referred
Do other bridge owners in our country follow the same inspection frequency as you do?	No		No		–		(-) means Questions was not referred

Are the inspection data integrated into a bridge management system program?	No	No	_		(-) means Questions was not referred
Do you have a computerized Bridge Management System (BMS)?	No	No	_		(-) means Questions was not referred
What requirements exist (if any) for emergency inspection?	None	_	_		(-) means Questions was not referred
If you don't have Computerized Bridge Management Software, what system are you using? How are you managing your bridges?	Manual System	Manual System	_		(-) means Questions was not referred
What is your railway bridge inspection system status?	under development	not fully developed	_		(-) means Questions was not referred
What is your bridge inspection condition rating scale?	Very poor, Poor, Fair, Good and Very good	Good, Fair and Bad	_		(-) means Questions was not referred
Famous Bridge Failures during the operation of the old railway line.	–	Harawa, Awash, Hol Hol and Afdem	_		(-) means Questions was not referred
What was the main reason for termination of operation of the old Ethio-Djibouti Railway Line?	–	poor management, unable to upgrade or modernize the company or railway line due to budget constraints, frequent accidents and bankruptcy	_		(-) means Questions was not referred
Briefly describe the systematic procedures of inspection use at a typical bridge	–	–	Arrive at the target bridge, Park at the safe space, Check the location data, Examine the entire bridge, Take the pictures of defects & Leave the bridge		(-) means Questions was not referred
Possible recommendation of the inspector team after inspecting the existing bridges with	–	–	Scour at pier and /or abutment	Rehabilitation, Preventive Maintenance or Corrective Maintenance	(-) means Questions was not referred
	–	–	Overtopping	Replacement, Preventive Maintenance or Corrective Maintenance	(-) means Questions was not referred
	–	–	Road and post crushing	Replacement, Rehabilitation, Preventive Maintenance or Corrective Maintenance	(-) means Questions was not referred
	–	–	Pot holes with Rebar exposure in Deck	Rehabilitation, Preventive Maintenance or Corrective Maintenance	(-) means Questions was not referred
	–	–	Water Leakage on Deck	Rehabilitation, Preventive Maintenance or Corrective Maintenance	(-) means Questions was not referred
	–	–	Shear Crack on Girder	Rehabilitation, Preventive maintenance, Corrective Maintenance or Replacement	(-) means Questions was not referred
	–	–	Flexural Crack	Rehabilitation, Preventive maintenance, Corrective Maintenance or Replacement	(-) means Questions was not referred
	–	–	Foundation settlement	replacement	(-) means Questions was not referred

3.7.4 Personnel Qualifications

Table 3-8: Response summary of Personnel Qualifications

Item Description	Response Summary			
	AALRT and ERC	Ethio-Djibouti Railway Company	Bridge Professionals	Remark
Which Personnel's are involved in railway bridge inspection?	Bridge Coordinator, Bridge Engineer, Bridge Inspector, Assistant Bridge Inspector and Track Engineer	Bridge Coordinator, Bridge Engineer and Bridge Inspectors	Bridge Inspection Team Leader, Bridge Coordinator, Bridge Engineer, Bridge Inspector and Assistant Bridge Inspector	
Are a personnel's involved in Railway Bridge inspection formally certified and are educational and physical qualifications required of inspectors?	Educational and physical qualifications for inspectors are required but, the inspectors are not formally certified	Educational and physical qualifications for inspectors are required but, the inspectors are not formally certified	Bridge inspection formally certified and educational and physical qualifications required	
Who certified Bridge Inspectors and who sets educational and physical qualifications required?	ERC	Franco-Ethiopian Railway Company	Bridge Owners	
Who sets educational and physical qualifications required of inspectors?	ERC	Franco-Ethiopian Railway Company	Bridge Owners	
How often are the inspectors trained?	in these companies no special training is provided	semiannually, annually or when needed	annually	
Who trains them?	in these companies no special training is provided for the Inspectors	Franco-Ethiopian Railway Company	Bridge Owners	

3.7.5 Inventory and Inspection Process

Table 3-9: Response summary of Inventory and Inspection Process

Item Description	Response Summary			
	AALRT and ERC	Ethio-Djibouti Railway Company	Bridge Professionals	Remark
Is there any prepared standards, procedures, manuals, guidelines?	No	Yes	_	(-) means Questions was not referred
What role does your Organization play in the process of ensuring quality and safety of railway bridges inventory and inspection?	Full role	Partial role	_	(-) means Questions was not referred

3.7.6 Facilities for Inventory and Inspection

Table 3-10: Response summary of Facilities for Inventory and Inspection

Item Description	Response Summary			
	AALRT and ERC	Ethio-Djibouti Railway Company	Bridge Professionals	Remark
What tool, Equipment and Facility are used for Inspection and Inventory?	furnished office, Computer, Printer and Other office tools, Inspector's safety (protective) equipment's and Different measuring Equipment's	Inspector's safety (protective) equipment's and Different measuring Equipment's	furnished office, Computer, Printer, Inspector's safety (protective) equipment's, Different measuring Equipment's, Inspection formats, Guidelines and different Bridge Inspection Manuals, High-rail cars	
What tool, Equipment and Facility were used for Train Accidents and Derailments?	_	An emergency train, loaded with lifting gear, Camping equipment and Food and water for Emergency teams	Emergency Inspection Personnel's, Stand by emergency equipment's like emergency train and emergency Crain, full facilities for camping at the bridge site like food and drink	(-) means Questions was not referred
Is any nondestructive evaluation, nondestructive testing?	No	No	Schmidt's rebound hammer for concrete to check soundness	
What remote monitoring technologies (if any) are being used to monitor bridges?	_	_	GPS	(-) means Questions was not referred

3.7.7 Documentation of Inventory and Inspection

Table 3-11: Response summary of Documentation of Inventory and Inspection

Item Description	Response Summary			
	AALRT and ERC	Ethio-Djibouti Railway Company	Bridge Professionals	Remark
Do standard inventory and inspection formats exist?	No	Yes, only for steel bridges	Yes	
For which types of inspection did the formats apply?	–	for Major Inspection	Regular and Major Inspections	(-) means Questions was not referred
What is the process of distribution, review and evaluation of inspection reports?	Inspector - Inspection Team Leader - Asset Management Department - Deputy Director General	bridge inspectors - Bridge Coordinator - Division Manager	bridge inspection team - bridge inspection coordinator - data entry programmer - bridge database	
Who reviews the inspection reports?	Asset Management Department Head	Division Manager	Bridge Inspection Coordinator / Bridge Management Team Leader and Bridge Engineer	
How long will be inspection records keep?	Keeping inspection record is not started	–	–	(-) means Questions was not referred

3.7.8 General Comments

Table 3-12: Response summary of General Comments

Item Description	Response Summary			
	AALRT and ERC	Ethio-Djibouti Railway Company	Bridge Professionals	Remark
What are the barriers that need to be overcome to implement Bridge Asset Management use?	–	–	Lack of staff, funding, training, support by upper management, commitment on the engineer & less payment	(-) means Questions was not referred
Are you satisfied with the bridge management of other Organizations in our country?	partially satisfied	partially satisfied by ERA	partially satisfied by ERA	
How could the bridge asset management system can be improved?	By establishing bridge asset management department with qualified bridge inspection personnel's and provide continuous training for this personnel's, Using bridge database system and Using recent and updated bridge inspection equipment's	NA	By establishing a bridge management team, training for the bridge inspectors, improving the data collection system, perform the inspection work by more skilled, , by using computerized bridge management system, by hiring private consultants	

3.8 Bridge Defects / Damages Weight and Severity

Response summary of bridge defects and severity of bridge defects by Bridge Professionals attached in Appendix G and Hypothesis Test on the response summary carried out to select the most appropriate values and presented in the following table.

Table 3-13: Hypothesis Testing for Railway Bridge Element Damage Weight and Severity of Defects

Percentage Importance of Railway Bridge Elements	Railway Bridge Elements and Corresponding Defects	H (x) (μ)	n	σ	H_0 (μ_0)	x-μ_0	σ/√n	Z calc	Zα			
%age Importance of railway bridge elements out of 100% of whole Bridge	Bridge Superstructure	34.54	24	6.48	32.63	1.91	1.32	1.44	1.65	μ>μ0	Zcalc < Zα	Accept H0
	Bridge Substructure	38.15	24	6.47	36.71	1.43	1.32	1.08	1.65	μ>μ0	Zcalc < Zα	Accept H0
	Bridge Ancillary	9.39	24	4.08	12.24	(2.84)	0.83	(3.42)	(1.65)	μ<μ0	Zcalc < Zα	Reject H0
	Railway Truck Structure over the bridge	18.41	24	6.58	18.41	0.00	1.34	0.00	1.65	μ>μ0	Zcalc < Zα	Accept H0
%age Importance of railway bridge RC Superstructure elements out of 100% of whole Bridge	Deck Slab	37.50	24	6.53	42.32	(4.82)	1.33	(3.61)	(1.65)	μ<μ0	Zcalc < Zα	Reject H0
	Concrete Girder	62.50	24	6.53	57.68	4.82	1.33	3.61	1.65	μ>μ0	Zcalc > Zα	Reject H0
%age Importance of railway bridge Steel Superstructure elements out of 100% of whole Bridge	Steel Deck	38.25	24	6.09	42.32	(4.07)	1.24	(3.27)	(1.65)	μ<μ0	Zcalc < Zα	Reject H0
	Steel Girder	61.75	24	6.09	57.68	4.07	1.24	3.27	1.65	μ>μ0	Zcalc > Zα	Reject H0
%age Importance of railway bridge Substructure elements out of 100% of whole Bridge	Pier & Foundation	40.91	24	3.43	44.47	(3.56)	0.70	(5.09)	(1.65)	μ<μ0	Zcalc < Zα	Reject H0
	Abutment & Wing wall	39.37	24	4.18	44.47	(5.10)	0.85	(5.98)	(1.65)	μ<μ0	Zcalc < Zα	Reject H0
	Embankment	11.32	24	4.65	6.67	4.66	0.95	4.90	1.65	μ>μ0	Zcalc > Zα	Reject H0
	Rip Rap	8.40	24	2.73	4.44	3.96	0.56	7.10	1.65	μ>μ0	Zcalc > Zα	Reject H0
%age Importance of railway bridge Ancillary elements out of 100% of whole Bridge	Bearing	47.13	24	11.38	31.80	15.34	2.32	6.60	1.65	μ>μ0	Zcalc > Zα	Reject H0
	Expansion Joint	18.90	24	6.51	15.90	3.00	1.33	2.26	1.65	μ>μ0	Zcalc > Zα	Reject H0
	Deck Drains	17.12	24	4.92	20.11	(2.99)	1.00	(2.98)	(1.65)	μ<μ0	Zcalc < Zα	Reject H0
	Kerb, Railing & Post	16.85	24	8.22	32.19	-15.35	1.68	(9.15)	(1.65)	μ<μ0	Zcalc < Zα	Reject H0
%age Importance of railway bridge Deck Slab Defects out of 100% of whole Deck Slab Defects	Cracking	30.78	24	8.69	44.12	-13.34	1.77	(7.52)	(1.65)	μ<μ0	Zcalc < Zα	Reject H0
	Peel off	10.88	24	2.98	8.82	2.05	0.61	3.38	1.65	μ>μ0	Zcalc > Zα	Reject H0
	Rebar Exposure	22.96	24	5.14	14.71	8.26	1.05	7.87	1.65	μ>μ0	Zcalc > Zα	Reject H0
	Honeycomb	9.65	24	4.00	5.88	3.77	0.82	4.61	1.65	μ>μ0	Zcalc > Zα	Reject H0
	Void	11.44	24	3.64	14.71	(3.26)	0.74	(4.39)	(1.65)	μ<μ0	Zcalc < Zα	Reject H0
	Water Leakage	14.51	24	4.85	11.76	2.74	0.99	2.77	1.65	μ>μ0	Zcalc > Zα	Reject H0
%age Importance of railway bridge Concrete Girder Defects out of 100% of whole Concrete Girder Defects	Cracking	30.88	24	6.08	34.77	(3.89)	1.24	(3.13)	(1.65)	μ<μ0	Zcalc < Zα	Reject H0
	Peel off	10.96	24	3.74	13.04	(2.08)	0.76	(2.72)	(1.65)	μ<μ0	Zcalc < Zα	Reject H0
	Rebar Exposure	23.73	24	5.42	19.60	4.12	1.11	3.73	1.65	μ>μ0	Zcalc > Zα	Reject H0
	Honeycomb	10.69	24	3.66	10.86	(0.18)	0.75	(0.23)	(1.65)	μ<μ0	Zcalc > Zα	Accept H0
	Void	11.04	24	3.60	10.86	0.17	0.74	0.23	1.65	μ>μ0	Zcalc < Zα	Accept H0
	Water Leakage	13.16	24	4.98	10.86	2.30	1.02	2.26	1.65	μ>μ0	Zcalc > Zα	Reject H0
%age Importance of railway bridge Steel Girder Defects out of 100% of whole Steel Girder Defects	Deformation	26.44	24	5.57	26.09	0.36	1.14	0.31	1.65	μ>μ0	Zcalc < Zα	Accept H0
	Cracking	22.44	24	7.84	26.09	(3.64)	1.60	(2.28)	(1.65)	μ<μ0	Zcalc < Zα	Reject H0
	Corrosion	17.44	24	5.03	13.04	4.40	1.03	4.29	1.65	μ>μ0	Zcalc > Zα	Reject H0
	Wearing	12.65	24	2.49	13.04	(0.40)	0.51	(0.78)	(1.65)	μ<μ0	Zcalc > Zα	Accept H0
	Bolt Missing	11.43	24	3.86	10.87	0.56	0.79	0.71	1.65	μ>μ0	Zcalc < Zα	Accept H0
	Paint Peel off	9.46	24	3.88	10.87	(1.41)	0.79	(1.78)	(1.65)	μ<μ0	Zcalc < Zα	Reject H0
%age Importance of	Cracking	20.75	24	4.66	20.00	0.75	0.95	0.79	1.65	μ>μ0	Zcalc < Zα	Accept H0

railway bridge Pier & Foundation Defects out of 100% of whole Pier & Foundation Defects	Peel off / Stone Deterioration	9.17	24	3.15	7.50	1.67	0.64	2.59	1.65	μ>μ0	Zcalc > Zα	Reject H0
	Rebar Exposure	13.56	24	2.61	15.00	(1.44)	0.53	(2.69)	(1.65)	μ<μ0	Zcalc < Zα	Reject H0
	Honeycomb	6.86	24	3.01	5.00	1.86	0.61	3.03	1.65	μ>μ0	Zcalc > Zα	Reject H0
	Void	5.47	24	1.45	5.00	0.47	0.30	1.58	1.65	μ>μ0	Zcalc < Zα	Accept H0
	Water Leakage	6.05	24	2.46	5.00	1.05	0.50	2.08	1.65	μ>μ0	Zcalc > Zα	Reject H0
	Displacement / Bulging	15.20	24	5.72	12.50	2.70	1.17	2.31	1.65	μ>μ0	Zcalc > Zα	Reject H0
	Scour	22.86	24	9.35	30.00	(7.14)	1.91	(3.74)	(1.65)	μ<μ0	Zcalc < Zα	Reject H0
%age Importance of railway bridge Abutment & Wing wall Defects out of 100% of whole Abutment & Wing wall Defects	Cracking	21.60	24	3.93	20.00	1.60	0.80	2.00	1.65	μ>μ0	Zcalc > Zα	Reject H0
	Peel off / Stone Deterioration	9.70	24	3.24	12.50	(2.80)	0.66	(4.23)	(1.65)	μ<μ0	Zcalc < Zα	Reject H0
	Rebar Exposure	12.96	24	2.82	10.00	2.96	0.58	5.14	1.65	μ>μ0	Zcalc > Zα	Reject H0
	Honeycomb	7.32	24	3.74	5.00	2.32	0.76	3.04	1.65	μ>μ0	Zcalc > Zα	Reject H0
	Void	6.13	24	2.06	5.00	1.13	0.42	2.68	1.65	μ>μ0	Zcalc > Zα	Reject H0
	Water Leakage	7.12	24	2.68	7.50	(0.38)	0.55	(0.69)	(1.65)	μ<μ0	Zcalc > Zα	Accept H0
	Displacement / Bulging	13.11	24	4.35	10.00	3.11	0.89	3.50	1.65	μ>μ0	Zcalc > Zα	Reject H0
	Scour	22.05	24	8.75	30.00	(7.95)	1.79	(4.45)	(1.65)	μ<μ0	Zcalc < Zα	Reject H0
%age Importance of railway bridge Embankment Defects out of 100% of whole Embankment Defects	Depression	39.56	24	13.22	33.33	6.23	2.70	2.31	1.65	μ>μ0	Zcalc > Zα	Reject H0
	Erosion	60.44	24	13.22	66.67	(6.23)	2.70	(2.31)	(1.65)	μ<μ0	Zcalc < Zα	Reject H0
%age Importance of railway bridge Rip Rap Defects out of 100% of whole Rip Rap Defects	Missing	33.95	24	7.62	25.00	8.95	1.56	5.75	1.65	μ>μ0	Zcalc > Zα	Reject H0
	Erosion	35.65	24	4.87	40.00	(4.35)	0.99	(4.38)	(1.65)	μ<μ0	Zcalc < Zα	Reject H0
	Displacement	30.74	24	5.82	35.00	(4.26)	1.19	(3.58)	(1.65)	μ<μ0	Zcalc < Zα	Reject H0
%age Importance of railway bridge Bearing Defects out of 100% of whole Bearing Defects	Main Damage	33.57	24	7.08	25.00	8.57	1.44	5.94	1.65	μ>μ0	Zcalc > Zα	Reject H0
	Parts Missing	13.52	24	3.16	20.00	(6.48)	0.65	(10.04)	(1.65)	μ<μ0	Zcalc < Zα	Reject H0
	Anchor Damage	15.14	24	5.26	15.00	0.14	1.07	0.13	1.65	μ>μ0	Zcalc < Zα	Accept H0
	Bed Damage	16.24	24	6.53	20.00	(3.76)	1.33	(2.82)	(1.65)	μ<μ0	Zcalc < Zα	Reject H0
	Unusual Movement	22.46	24	4.66	20.00	2.46	0.95	2.59	1.65	μ>μ0	Zcalc > Zα	Reject H0
%age Importance of railway bridge Expansion Joint Defects out of 100% of whole Expansion Joint Defects	Deformation	22.15	24	6.09	15.00	7.15	1.24	5.75	1.65	μ>μ0	Zcalc > Zα	Reject H0
	Water Leakage	22.59	24	6.94	25.00	(2.41)	1.42	(1.70)	(1.65)	μ<μ0	Zcalc < Zα	Reject H0
	Peel off	16.61	24	4.72	25.00	(8.39)	0.96	(8.72)	(1.65)	μ<μ0	Zcalc < Zα	Reject H0
	Missing	19.41	24	3.81	20.00	(0.59)	0.78	(0.76)	(1.65)	μ<μ0	Zcalc > Zα	Accept H0
	Noise	19.24	24	4.10	15.00	4.24	0.84	5.07	1.65	μ>μ0	Zcalc > Zα	Reject H0
%age Importance of railway bridge Kerb & Railing Defects out of 100% of whole Kerb & Railing Defects	Cracking	18.92	24	5.21	18.75	0.17	1.06	0.16	1.65	μ>μ0	Zcalc < Zα	Accept H0
	Peel off	13.28	24	4.92	12.50	0.78	1.00	0.78	1.65	μ>μ0	Zcalc < Zα	Accept H0
	Rebar Exposure	16.12	24	4.78	12.50	3.62	0.98	3.71	1.65	μ>μ0	Zcalc > Zα	Reject H0
	Deformation	19.14	24	2.30	18.75	0.39	0.47	0.82	1.65	μ>μ0	Zcalc < Zα	Accept H0
	Corrosion	13.15	24	4.20	12.50	0.65	0.86	0.75	1.65	μ>μ0	Zcalc < Zα	Accept H0
	Missing	17.58	24	5.65	25.00	(7.42)	1.15	(6.43)	(1.65)	μ<μ0	Zcalc < Zα	Reject H0
%age Importance of railway bridge Drainage Defects out of 100% of whole Drainage Defects	Pipe Damage	38.01	24	10.67	44.00	(5.99)	2.18	(2.75)	(1.65)	μ<μ0	Zcalc < Zα	Reject H0
	Blocked	35.74	24	9.57	24.00	11.74	1.95	6.01	1.65	μ>μ0	Zcalc > Zα	Reject H0
	Inlet Damage	26.25	24	6.96	32.00	(5.75)	1.42	(4.05)	(1.65)	μ<μ0	Zcalc < Zα	Reject H0
Railway Bridge Defects	**Bridge Defect Rating**											
Cracking RC Bridge (mm)	New	0.13	24	0.01	0.50	(0.38)	0.00	-217.52	1.65	μ<μ0	Zcalc < Zα	Reject H_0
	Minor	0.63	24	0.04	1.50	(0.87)	0.01	-100.13	1.65	μ<μ0	Zcalc < Zα	Reject H_0
	Moderate	2.00	24	0.14	2.50	(0.50)	0.03	(18.13)	1.65	μ<μ0	Zcalc < Zα	Reject H_0
	Sever	4.00	24	0.27	4.00	-	0.06	-	1.65			H1 = H0
	Failed	5.00	24	0.34	5.00	-	0.07	-	1.65			H1 = H0
Peel Off (cm^2)	New	12.50	24	0.84	0.00	12.50	0.17	72.51	1.65	μ>μ0	Zcalc > Zα	Reject H_0
	Minor	112.0	24	7.57	176.0	-64.00	1.54	(41.43)	1.65	μ<μ0	Zcalc < Zα	Reject H_0

	Moderate	480.0	24	32.4	650.0	-170.0	6.62	(25.68)	1.65	μ<μ0	Zcalc < Zα	Reject H_0
	Sever	880.0	24	59.4	900.0	-20.00	12.14	(1.65)	1.65	μ<μ0	Zcalc < Zα	Reject H_0
	Failed	2200	24	148.	2200	-	30.34	-	1.65			H1 = H0
Void (cm^3)	New	16.00	24	1.08	0.00	16.00	0.22	72.51	1.65	μ>μ0	Zcalc > Zα	Reject H_0
	Minor	316.0	24	21.3	300.0	16.00	4.36	3.67	1.65	μ>μ0	Zcalc > Zα	Reject H_0
	Moderate	700.0	24	47.3	800.0	-100.0	9.65	(10.36)	1.65	μ<μ0	Zcalc < Zα	Reject H_0
	Sever	975.0	24	65.9	1000	-25.00	13.45	(1.86)	1.65	μ<μ0	Zcalc < Zα	Reject H_0
	Failed	1150	24	77.7	1150	-	15.86	-	1.65			H1 = H0
End Block Damage (Pre stressed Concrete Bridge) (mm)	New	0.00	24	0.00	0.00	-	-		1.65			H1 = H0
	Minor	0.25	24	0.02	0.05	0.20	0.00	58.00	1.65	μ>μ0	Zcalc > Zα	Reject H_0
	Moderate	1.25	24	0.08	0.16	1.09	0.02	63.23	1.65	μ>μ0	Zcalc > Zα	Reject H_0
	Sever	2.50	24	0.17	0.20	2.30	0.03	66.71	1.65	μ>μ0	Zcalc > Zα	Reject H_0
	Failed	3.00	24	0.20	0.23	2.77	0.04	66.95	1.65	μ>μ0	Zcalc > Zα	Reject H_0
Pier, Abutment, Wing wall and Foundation Displacement (mm)	New	1.65	24	0.11	0.00	1.65	0.02	72.51	1.65	μ>μ0	Zcalc > Zα	Reject H_0
	Minor	8.50	24	0.57	12.50	(4.00)	0.12	(34.12)	1.65	μ<μ0	Zcalc < Zα	Reject H_0
	Moderate	22.50	24	1.52	37.50	-15.00	0.31	(48.34)	1.65	μ<μ0	Zcalc < Zα	Reject H_0
	Sever	40.60	24	2.74	45.00	(4.40)	0.56	(7.86)	1.65	μ<μ0	Zcalc < Zα	Reject H_0
	Failed	50.00	24	3.38	50.00	-	0.69	-	1.65			H1 = H0
Embankment Depression (mm)	New	0.00	24	0.00	0.00	-	-		1.65			H1 = H0
	Minor	6.90	24	0.47	12.50	(5.60)	0.10	(58.85)	1.65	μ<μ0	Zcalc < Zα	Reject H_0
	Moderate	22.50	24	1.52	37.50	-15.00	0.31	(48.34)	1.65	μ<μ0	Zcalc < Zα	Reject H_0
	Sever	40.60	24	2.74	43.80	(3.20)	0.56	(5.71)	1.65	μ<μ0	Zcalc < Zα	Reject H_0
	Failed	50.00	24	3.38	50.00	-	0.69	-	1.65			H1 = H0

Note:

H (x) (μ) Alternative or Research Hypothesis (Average Value from Questioner)

n Number of Sample

σ Standard Deviation of Values from Questioner

μ_0 (H_0) Null Hypothesis (From Literature Review) [6, 26 & 27]

Z_α Values obtained from Critical values of the t distribution table at level of significance (α) = 5%

Z_{calc}

$$Z \equiv \frac{\overline{X} - \mu_0}{\sigma / \sqrt{n}}$$

Response summary of the Questioner

- Inventory and Inspection of Railway Bridges in ERC & AALRT is not started. In addition to this, Inventory and Inspection formats are not available.
- Severity of Railway Bridge defects are ratted / ranked as new condition, minor, moderate, sever and failed condition.

- Extents of bridge defect / damage are ratted / ranked as No Significant defect, Slight, Moderate, Wide and Extensive.
- Relevancy of defect / damage are ratted / ranked as No significant, Minor, Moderate, Major and Critical.

Overall, the following findings are obtained from the questioner:

- types and frequencies of Railway Bridge Inspection
- The standard procedure of railway bridge inventory and inspection
- Facility required for Railway Bridge Inventory and Inspection.
- Bridge inspection investigation techniques
- Safety measures during inventory and inspection.
- Personnel's required for bridge inventory and inspection,
- Reporting inventory and inspection findings

4. GUIDELINE FOR INVENTORY AND INSPECTION

4.1 Railway Bridges Inventory

The bridge inventory is developed to have a unified database for bridges including identification information, bridge types and specifications and bridge data including geometric data, functional description, etc. Identification information addresses the bridge location uniquely and classifies the type of the routes carried out on and/or under the structure. Bridge type and specifications classify the type of the bridge. This part provides defined standard categories for classifying bridges. It also identifies the material of the bridge components, deck and deck surface. Operational conditions provide information about the age of the bridge as well as construction year, rehabilitation year, type of services and traffic carried over and/or under the bridge. Furthermore, the bridge inventory contains information regarding geometry.

Currently, the AALRT providing service despite performing Inventory works on railway bridges. Still now the total number of railway bridges in AALRT is not known. Therefore, now is the time to carry out the bridge inventory.

Based on the condition of Railway Bridges in ERC and AALRT, all cross drainage structures with a span length of ≥ 6.0m are included as a Bridge in this Guideline. All bridges in ERC and AALRT's are in new / good condition. Drainage structures with a span < 6.0m are considered in culverts.

4.1.1 Inventory Format

Two formats are prepared where Format A, Figure 4-1, is to be used by Expert to be filled during Inventory, while Format B, Figure 4-2, is used to Guide and make selection for filling Format A.

RAILWAY BRIDGE INVENTORY FORMAT A

TYPE OF INVENTORY .....

RAILWAY LINE No	RAILWAY LINE NAME	SUB RAILWAY LINE No	SUB RAILWAY LINE NAME	RAILWAY LINE CLASS / FUNCTIONAL CLASSIFICATION	BRIDGE No	BRIDGE NAME	COORDINATES
							X =
							Y =

GENERAL INFORMATION		TRACK STRUCTURE		SUPER STRUCTURE		SUBSTRUCTURE AND FOUNDATION		ANCILLARIES	
LOCATION, Km		NO. OF TRACK LINE / LANE		STRUCTURE TYPE, MAIN		ABUTMENT TYPE A1		TYPE OF EXPANSION JOINT	
OVERLL BRIDGE LENGTH, Mt		TRUCK GAUGE mm		STRUCTURE TYPE, APPROACH SPANS		ABUTMENT TYPE A2		TYPE OF GUARD RAILING	
OVERALL BRIDGE WIDTH, Mt		SPACE BETWEEN TRACK LINES, Mt		NUMBER OF SPANS IN MAIN UNIT		HEIGHT OF ABUTMENT A1,Mt		TYPE OF ABUTMENTS BEARING	
RIVER WIDTH, Mt		RAIL TYPE		NUMBER OF APPROACH SPANS		WIDTH OF ABUTMENT A1, Mt		TYPE OF PIERS BEARING	
PRESENT WATER LEVEL, Mt		TRACK GUARD RAIL Y/N		LENGTH OF MAXIMUM SPAN, Mt		TICKNESS OF ABUTMENT A1, Mt			
HIGHEST WATER LEVEL, Mt		RAIL JOINT FASTENING Y/N		SPAN COMPOSITION		HEIGHT OF ABUTMENT A2,Mt			
AREA TOPOGRAPHY		RAIL EXPANSION GAP, Mm		TOTAL SPAN LENGTH, Mt		WIDTH OF ABUTMENT A2 , Mt			
YEAR OF CONSTRUCTION		DECK SLAB TYPE		TOTAL BRIDGE WIDTH, Mt		TICKNESS OF ABUTMENT A2, Mt			
CONTRACTOR		SLEEPER TYPE		SPAN CONFIGURATION		WING WALL LENGTH,Mt			
DESIGNER / SUPERVISOR		SLEEPER SPACING Cm		DECK SLAB TYPE		TYPE OF PIERS			
COST OF THE BRIDGE, Br		RAILROAD BRIDGE DECK TYPE		SLAB THICKNESS, cm		NO. OF PIERS			
DESIGN LOAD CAPACITY, Ton		BALLAST THICKNESS , Cm		NO. OF GIRDER / BOX		HEIGHT OF PIER 1,2,3...			
HEAVIEST LOCOMOTIVE IN USE, Ton				DEPTH OF GIRDER / BOX		WIDTH OF PIERS 1,2,...			
AVERAGE DAILY TRAIN TRAFFIC				SPACING OF GIRDER / BOX ,Mt		TICKNESS OF PIERS 1,2...			
DESIGN SPEED, K/h				WIDTH OF GIRDER / BOX ,Mt		MINIMUM LATERAL UNDERCLERANCE ON RIGHT, Mt			
RAILWAY ALIGNMENT, CURVE / STRAIGHT				TYPES OF PRESTRESS		MINIMUM LATERAL UNDERCLERANCE ON LEFT, Mt			
SAFETY / LOAD LIMIT SIGN				MINIMUM VERTICAL CLEARANCE OVER BRIDGE RAILWAY, Mt		TYPE OF ABUTMENT FOUNDATION			
ALTITUDE, Mt						TYPE OF PIER FOUNDATION			
HIGHEST TEMPERATURE, ^{0}C				TYPE OF ABUTMENTS BEARING		ABUTMENT FOUNDATION SIZE			
LOWEST TEMPERATURE, ^{0}C				TYPE OF PIERS BEARING		PIER FOUNDATION SIZE			
SERVICE CARRIED ON THE BRIDGE						NO.OF ABUTMENT PILES			
OWNERSHIP OF SERVICE CARRIED						NO.OF PIER PILES			
PRIMARY FUNCTION						ABUTMENT PILE DEPTH			
SECONDARY FUNCTION						PIER PILE DEPTH			
SKEW ANGLE, ^{0}									
TYPES OF TRANSPORT									
DATA SOURCE									
CONCRETE GRADE, Mpa									
STEEL GRADE, Mpa									
BRIDGE DESIGN CODE									

Comments:

TYPES TO BE SELECTED FROM FORMAT B

INSPECTOR NAME .....

SIGNATURE .....

DATE .....

Figure 4-1: Format A, Railway Bridge Inventory format

TYPE OF INVENTORY
NEW STRUCTURE
REPLACEMENT STRUCTURE
REHABILITATION
EXISTING STRUCTURE

SAFETY / LOAD LIMIT SIGN
LOAD LIMIT
SPEED LIMIT
RESTRICTION SIGNS LIKE VERTICAL AND HORIZONTAL CLEARANCE
BRIDGE APPROACH

SERVICE CARRIED ON THE BRIDGE
SEWERAGE
TELECOM
WATER
ELECTRICITY
STREET LIGHTING

OWNERSHIP OF SERVICE CARRIED
RAILWAY CORPORATION
LOCAL AUTHORITY
WATER AND SEWERAGE AUTHORITY
ETHIO TELECOM
ELECTRIC POWER CORPORATION
PRIVATE

PRIMARY FUNCTION
RAIL BRIDGE
ROAD BRIDGE
PEDESTRIAN BRIDGE
RAIL & ROAD BRIDGE

SECONDARY FUNCTION
OVER RAIL
OVER ROAD
OVER WATER
PEDESTRIAN UNDERPASS

TYPES OF TRANSPORT
PASSENGER
FRAIGHT
MIXED

DATA SOURCE
DESIGN DRAWINGS
SITE INSPECTION

RAIL TYPE (CHINESE NATIONAL RAILWAYS)
43 KG/M
50 KG/M
60 KG/M

DECK SLAB TYPE
BALLASTED DECK
OPEN DECK

SLEEPER TYPE
CONCRETE
STEEL
WOODEN

RAILROAD BRIDGE DECK TYPE
BALLAST DECKS
OPEN DECKS
DIRECT FIXATION DECKS

STRUCTURE TYPE, MAIN & APPROACH
A/ PRESTRESED CONCRETE
PRECAST BOX GIRDER
CAST IN PLACE BOX GIRDER
PRECAST I - BEAM
PRECAST INTEGRAL BEAM AND SLAB
PRECAST BOX UNITS
RIGID FRAME BRIDGE
PRECAST SLAB PANEL
B/ REINFORCED CONCRETE - RCBR
BOX GIRDER
DECK GIRDER
CAST IN PLACE BOX UNITS
SLAB
C/ STEEL CONCRETE COMPOSITE - SCBR
STEEL BEAMS & CONCRETE DECK
D/ STEEL - STBR
I-BEAM
TRUSS

SPAN CONFIGURATION
SIMPLE SPAN
MULTI SPAN
CONTINUOUS SPAN
CANTILEVER BRIDGE

DECK SLAB TYPE
INSITU REINFORCED CONCRETE
INSITU PRESTRESSED CONCRETE
PRECAST PRESTRESSED CONCRETE
PRECAST REINFORCED CONCRETE
STEEL

TYPES OF PRESTRESS
PRE TENTION
POST TENTION

ABUTMENT TYPES
MASONRY
RC

TYPE OF PIERS
MASONRY WALL
RC COLUMN
RC WALL
RC RIGID-FRAME

TYPES OF ABUTMENT AND PIER FOUNDATION
CLASS `C` CONCRETE
RC DIRECT/MAT
RC-PILE
PC-PILE
STEEL-PIPE
CAISSON

TYPE OF EXPANSION JOINT
BLIND OR DUMMY
FILLED /CHEAPWOOD
RUBBER
STEEL (FINGER)
STEEL SHEET

TYPE OF GUARD RAILING
MASONRY
RC
STEEL
RC/STEEL COMPOSITE

TYPE OF ABUTMENTS & PIERS BEARING
STEEL LINE PLATE
PIN CONNECTED
BEARING-PLATE
STEEL ROLLER
RUBBER

Figure 4-2: Format B, Railway Bridge Inventory format

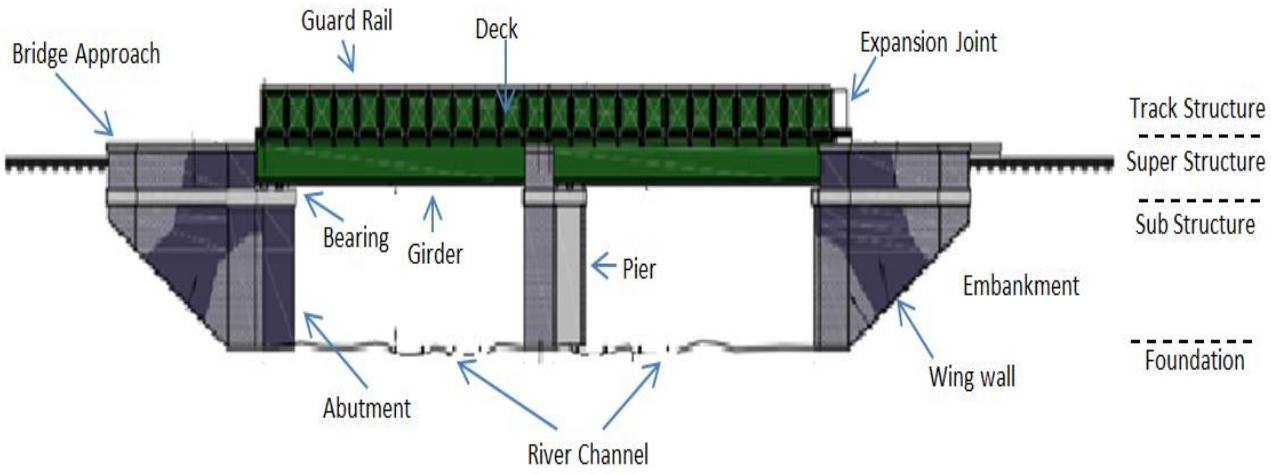


Figure 4-3: Schematic sketch (Profile) of a bridge

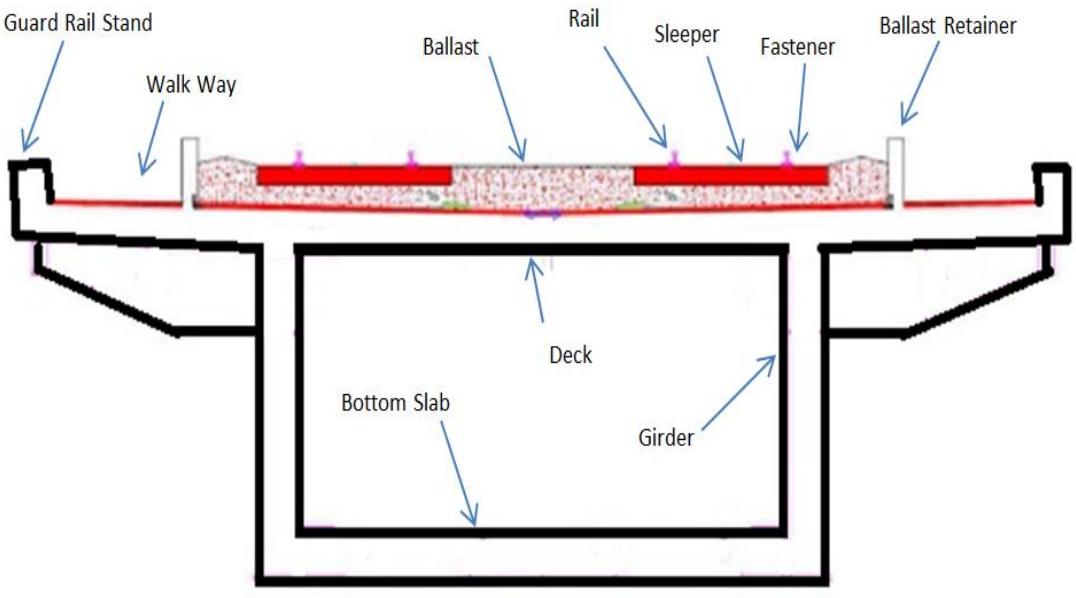


Figure 4-4: Schematic sketch of bridge components

Table 4-1: Bridge Inventory Parts Guide

<table>
<tr><th>Type of Inventory</th><th>Bridge Location</th><th colspan="2">General Information</th><th>Track Structure</th><th colspan="2">Super Structure</th><th colspan="2">Substructure and Foundation</th><th>Ancillaries</th></tr>
<tr><td rowspan="4">It is carried out Once when,

New Structure construction is completed

Existing Structure is replaced

Existing Structure is rehabilitated</td><td rowspan="3">Bridge ID-designed using Sub railway line. For example, Sebeta-Djibouti (01) sub divided in to Sebeta-Modjo (01-01), Modjo-Awash (01-02), Awash-Meiso (01-03), Meiso-Diredawa (01-03) and Diredawa-Dewnle (01-04) and then a unique ID number for the Bridges</td><td>Overall bridge length</td><td>Cost of the bridge</td><td>No. of track line: single track, double track and triple track</td><td colspan="2">Types of Bridges</td><td colspan="2" rowspan="2">Abutment type: masonry or concrete</td><td rowspan="4">Type of expansion joint: can be blind or dummy, filled /cheap wood, rubber, steel (finger) or steel sheet</td></tr>
<tr><td rowspan="3">Overall bridge width</td><td rowspan="3">Design load capacity</td><td rowspan="2">Truck gauge: narrow, standard or wide gauge</td><td rowspan="8">Prestresed Concrete</td><td>precast box girder</td></tr>
<tr><td>Cast in place box girder</td></tr>
<tr><td rowspan="3">C/C Space between track lines</td><td>precast i - beam</td><td colspan="2" rowspan="2">Type of piers: masonry wall, RC column, RC wall or RC rigid-frame</td></tr>
<tr><td>precast integral beam and slab</td></tr>
<tr><td>River width</td><td rowspan="2">Heaviest locomotive in us</td><td rowspan="2">Precast slab panels</td><td colspan="2" rowspan="2">Type of abutment and pier foundation: Class `c` concrete, RC direct/mat, RC-pile or RC-pile Steel-pipe, caisson</td></tr>
<tr><td rowspan="2">Rail type: 43kg/m, 50kg/m or 60 kg/m</td></tr>
<tr><td>Present water level</td><td>Average daily train traffic</td><td>precast box units</td><td rowspan="2">Type of guard railing: can be masonry, RC, steel or RC/steel composite</td></tr>
<tr><td rowspan="3">GPS location taken at the center of the bridges</td><td rowspan="2">Highest water level</td><td rowspan="2">Design speed</td><td rowspan="2">Track guard rail & Rail joint fastening</td><td>rigid frame bridge</td><td colspan="2" rowspan="2">Type of abutment and pier foundation: Class `c` concrete, RC direct/mat, RC-pile or RC-pile Steel-pipe, caisson</td></tr>
<tr><td rowspan="4">Reinforced Concrete</td><td>box girder</td></tr>
<tr><td rowspan="2">Rail expansion gap</td><td>deck girder</td><td colspan="2" rowspan="3">Dimensions of the Superstructure</td></tr>
<tr><td rowspan="2">Area topography</td><td rowspan="2">Railway alignment, curve / straight</td><td>cast in place box units</td></tr>
<tr><td rowspan="2">Sleeper type: can be concrete, wooden or steel</td><td>Arch bridge</td></tr>
<tr><td rowspan="2">Skew angle</td><td rowspan="2">Safety / load limit sign</td><td>slab</td></tr>
<tr><td rowspan="2">Composite</td><td rowspan="2">steel beams & concrete deck</td></tr>
<tr><td rowspan="3">Existing Structure handed over to Other Owner</td><td rowspan="3">Location in KM is measured from terminal stations. Example, Sebeta station of Addis Ababa</td><td rowspan="2">Year of construction</td><td rowspan="2">Altitude</td><td rowspan="2">Sleeper spacing</td><td rowspan="2">Steel</td><td>Truss</td></tr>
<tr><td>I-beam</td></tr>
<tr><td colspan="2">Span composition: can be simple span, multi span, continuous span or cantilever bridge</td><td rowspan="3">Height, Width and Thickness of abutment A1 &A2</td><td rowspan="3">Pier foundation size</td><td rowspan="4"></td></tr>
<tr><td rowspan="3">Contractor Name</td><td rowspan="3">Highest temperature and Lowest temperature</td><td rowspan="4">Railroad bridge deck type: ballasted deck, open deck or direct fixation deck</td><td colspan="2">Deck slab type: in situ reinforced concrete, in situ pre stressed concrete, precast pre stressed concrete, precast reinforced concrete or steel</td></tr>
<tr><td colspan="2">Types of pre stress: post tension or pre tension</td><td rowspan="2">Wing wall length, mt</td><td rowspan="2">No. of abutment piles</td></tr>
<tr><td rowspan="2">Designer / supervisor Name</td><td rowspan="2">Bridge design code</td><td colspan="2">Type of abutment and pier bearing: Steel line plate, Pin connected, Bearing-plate, Steel roller or Rubber</td></tr>
<tr><td colspan="2">Dimentions of the Superstructure</td><td rowspan="2">No. of piers</td><td rowspan="2">No. of pier piles</td></tr>
<tr><td colspan="2" rowspan="3">Service carried on the bridge: include sewerage, telecom, water, electricity and street lighting</td><td rowspan="3">Ballast thickness</td><td>Total span length, mt</td><td>Spacing of girder / box, mt</td></tr>
<tr><td>Total bridge width, mt</td><td>Width of girder / box, mt</td><td rowspan="2">Height, Width and Thickness of pier 1, 2, 3…</td><td rowspan="2">Abutment pile depth</td></tr>
<tr><td colspan="2" rowspan="2">Primary function of the bridge: includes Rail Bridge, Road Bridge, pedestrian bridge and rail & Road Bridge</td><td>Span configuration</td><td>Number of spans in main unit</td></tr>
<tr><td colspan="2" rowspan="2">Secondary function: can be over rail, over road, over water and pedestrian underpass</td><td rowspan="2">Deck Type: Ballasted or open deck</td><td>Slab thickness, cm</td><td>Number of approach spans</td><td rowspan="2">Minimum lateral under clearance on right & left, mt</td><td rowspan="2">Pier pile depth</td></tr>
<tr><td>No. of girder / box</td><td>Length of maximum span, mt</td></tr>
</table>

		Types of transport: can be passenger, freight or mixed		Depth of girder / box	Minimum vertical clearance over bridge railway, m	Abutment foundation size		

4.2 Railway Bridges Inspection

4.2.1 Types of Bridge Inspection

Bridge inspections are classified into four types in terms of purposes and frequencies.

A. Initial Inspection: is carried to obtain detailed general information of the bridge that includes photographs, bridge dimensions and member sizes, and member-specific data of any deterioration. It is carried first time for bridge file, where there is change in configuration of structure.

B. Regular Inspection: carried to check on the overall safety and performance of the structure and the identification of any minor and major accident damage or incident and any obvious failure of structural components. The method of inspection is visual and carried out in a fixed time interval.

C. Major Inspection: carried to assess and record the physical condition of structural components of the bridge and to ensure that the bridge is adequate to safely carry the intended loads. In this inspection quantitative data on structural components are collected for use in engineering analyses and deterioration models. The method of investigation is detailed visual inspection where all components are inspected closely (within 1.0 m) and nondestructive test and carried out in a fixed time interval.

D. Emergency Inspection: carried to evaluate damage to a bridge caused by flood, earthquake, derailment, collision or other unusual occurrences, to provide information on structural safety and safe train traffic condition and to judge necessity of emergency measures.

4.2.2 Frequency of Bridge Inspection

A. Initial Inspection

For the bridges along the Ethio-Djibouti Railway line, Initial Inspection needs be carried 3 months after the bridge owner's handover the bridge assets. Within 3 months the bridge owners needs to receive the bridge documents from Bridge Design Consultants and start to handle bridge database. This shall form the beginning of Railway Bridge Management System.

B. Regular Inspection

The old Ethio-Djibouti railway line station distribution is shown in the table below:

Table 4-2: The old Ethio-Djibouti railway line station distribution

Addis Ababa	Bole Keep	Nifas Silk	Kality	Akaki	Dallota	Dukem	Chelelek	Debrezeit	Denkala	Modjo
Tede	Aroge Adama	Nazrait	Soloke	Welenchity	Feto	Borchota	Melka Jiru	Haro Arba	Sabober	Metehara
Legebenti	Elilsala	Awash	Awash East	Hafdim	Awash Arba	Kora	Asebot	Meisso	Mulu	Afdem
Bike	Gota	Errer Bota	Errer	Kurso	Dire Dawa	Shillile	Harewa	Mello	Adigala	Gaserat
Aicha	Dewenle	Ailsabiet	Dasibu	Holl-Holl	Chebelle	Dijibouti				
Note:		Passenger Station			Freight Station					

In each of the above stations, there is a team who carried out Visual / Regular Inspection of the railway track and the bridges every day. On each day half of the station team inspects the track and bridges in one direction and the other half in the opposite direction. The average distance between consecutive stations was about 7km -14 km, which means that the half team had to inspect half of 7km -14 km in each day. And findings of any defects were reported for maintenance. Everyday inspection was carried out because of the railway line and the bridges were too old and proper maintenance was not carried out. This everyday inspection interval is not appropriate for the AALRT and ERC Railway lines, since the characteristics of bridges as well as the current quality condition of the pre stress bridges.

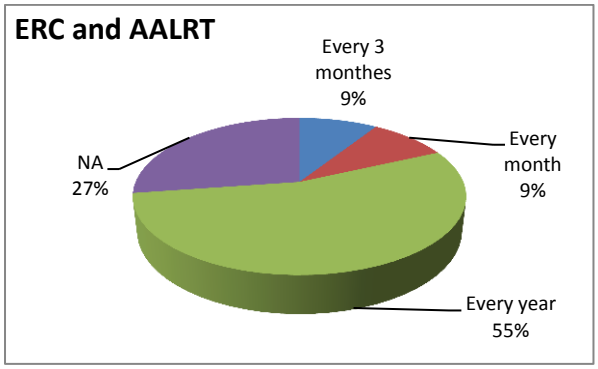
Currently, the AALRT carried out routine inspection work for track equipment in which track equipment is inspected during train outage time at night. This inspection interval is not appropriate, since method of regular inspection is just by visual observation. This means that regular inspection of the railway bridges shall be carried out during day time. Inspecting bridges everyday needs more inspection personnel's and high cost.

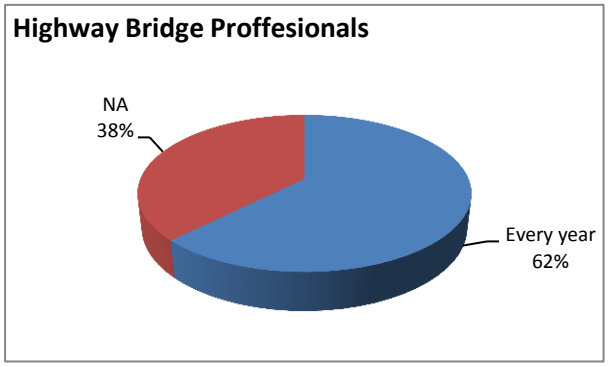
Other type of inspection that is carried out by AALRT is the track's static check cycle which means that the whole line will be checked monthly. During this time the inspection team can visually observe the overall safety and performance of the railway track and the identification of any minor and major accident damage or incident and any obvious failure of bridge structural components can be reported to the bridge asset management team. The inspection speed shall not exceed 3km/h.

Monthly inspection is one static equipment inspection with complete items conducted by the track shift for track equipment under administration every month. The track shift shall comprehensively inspect the equipment, make efforts to master change rules of equipment

and do well status survey for preparation of next month track equipment maintenance plan. Inspection dead track is before 25th of every month, if any urgent adjustment, notify the track professional skill team.

The findings of the questioner with respect to Regular inspection are as follow:



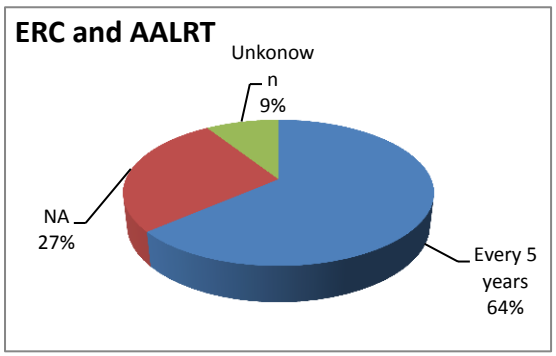


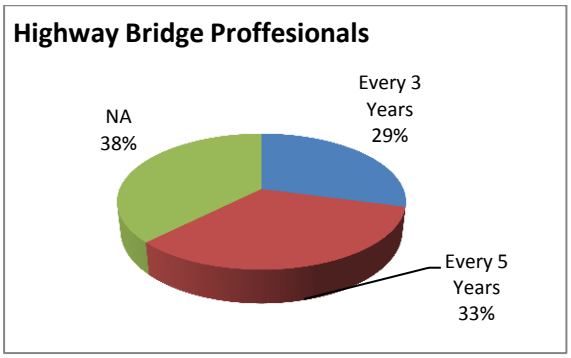
From the above chart 55% of AALRT and ERC respondents and 62% of Highway Bridge Professionals prefers the regular inspection to be carried every year. Most respondents from highway professionals use Ethiopian Roads Authority Bridge Inspection Manual. According to this manual, the Regular Inspection shall be carried out every year.

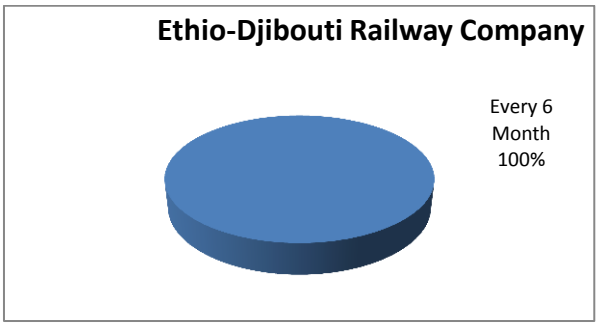
Further to this, most Railway Companies in USA, Australia and India and famous bridge inspection manuals like AREMA and AASHTO recommend railway bridges shall be visually inspected once in every year.

Therefore, Regular Inspection for railway bridges can be proposed to carried out every year. This inspection shall be carried out based on following bridge inspection manuals. This inspection shall be carried out during day time in order to inspect the bridge components with adequate sun light.

C. Major Inspection





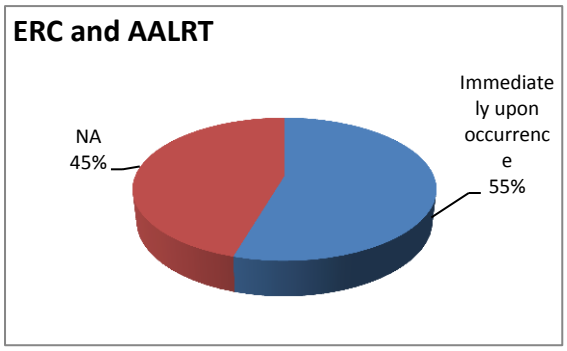


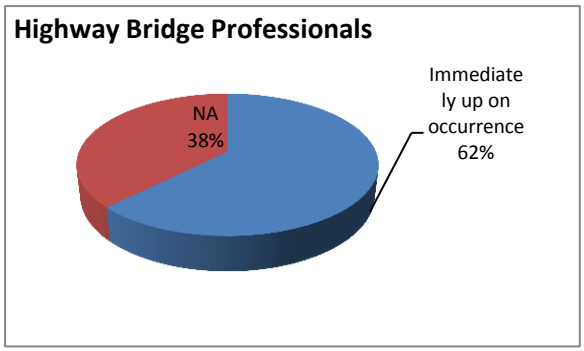
From the above chart 64% of AALRT and ERC respondents prefer the Major Inspection to be carried out every five years in similar way, 33% of Highway Bridge Professionals prefers the Major Inspection to be carried out every five years, 29% of Highway Bridge Professionals prefers the Major Inspection to be carried out every three years and Major Inspection on Ethio-Djibouti Railway Line was Carried out every six months.. Most respondents from highway professionals use Ethiopian Roads Authority Bridge Inspection Manual. According to this manual, the Major Inspection shall be carried out every three years. But, this inspection interval is not relevant for railway bridges in AALRT and ERC. This is because most of the highway bridges which are owned by Ethiopian Roads Authority were constructed during the Italian invasion and most of the bridges are complete their design life. In such kind of situation the inspection interval shall be smaller. Furthermore, there is a high shortage of bridge inspection personnel's, budget and lack of support by upper management.

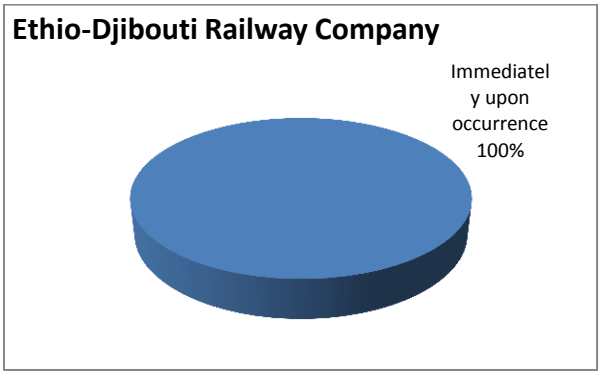
Further, the Railway Companies in Australia and India recommend railway bridges carrying major inspection every five years interval.

On the other hand, in AALRT and ERC all bridges are less than five years old and most of these bridges are pre stress concrete which are very durable. Therefore, the inspection interval for Major Inspection can be five years.

D. Emergency Inspection







From the above chart 55% of AALRT and ERC, 62% Highway Professional and 100% of Ethi-Djibouti Railway Company respondents prefer the Emergency Inspection to be carried out immediately up on occurrence.

Unlike other types of bridge inspections, most of literature and manuals agrees on the frequency of emergency inspection. Most literatures and manuals recommend the frequency of emergency inspection shall be immediately up on occurrence.

Therefore, the interval of Emergency inspection shall be immediately up on the accident occurrence, In this regard there has to be a stand by Emergency team when emergency is break out.

4.2.3 Rating / Ranking Severity of Railway Bridge Defects

Because the rating system reflects the specific conditions and desirable interventions, inspectors shall strictly follow the rating (ranking) description table.

Table 4-3: Rating / Ranking Severity of Railway Bridge Defects

Rating (Ranking)	Condition	Desirable Intervention
Failed	Serious damages, defects, and deterioration causing bridge components to be not functional	Emergency Inspection and Urgent repair / Replacement
Sever	Serious/major damages, defects, and deterioration causing reduction of load carrying capacity	Urgent repair
Moderate	Major damages, defects, and deterioration affecting reduction of durability	Repair but not urgent
Minor	Minor defects and deterioration	Routine maintenance
New	No damages defects and deterioration	Regular Inspection

Factors attribute to the deteriorate condition of bridges over time are live load, flood, earthquake, collision, environmental factors and fatigue**.**

The AALRT, ERC and Ethio-Djibouti Railway Companies do not have Railway Bridge Defects Rating / Ranking system. In this respect, the Ethiopian Roads Authority has best experience in our country. It is also appropriate to use the ERA Bridge Inspection Manual and other countries experience. Most of the questioner respondents have good experience in bridge inspection. Using the bridge defect rating values from literature review and experience from bridge inspectors, values are hypothetically tested and a summary table presented as follow.

Table 4-4: Rating Bridge Defects

Railway Bridge Defects	Bridge Defect Rating				
	New Condition	Minor Defect	Moderate Defect	Sever Defect	Failed
Cracking (RC Bridge)	None to Single crack width of less than 0.25mm & Spacing of cracks > 3m or multiple hairline crack	Single crack width of between 0.25mm-1.00mm & Spacing of cracks 2m-3m or multiple crack width of less than 0.25mm with no water leakage	Single crack width of between 1mm-3mm & Spacing of cracks 1m-2m or multiple cracks width of less than 1 mm, together with slight water leakage which causes reduction in durability	Single crack width of between 3mm-5mm & Spacing of cracks 1m-0.5m or multiple cracks width of less than 3 mm, together with water leakage, free lime or salt which causes reduction in loading capacity	Single crack width of greater than 5mm & Spacing of cracks < 0.5m or multiple cracks width of less than 5 mm, together with water leakage, free lime or salt which causes the bridge elements not to support & transfer the load
Cracking (Prestress Bridge)	None to Hairline Cracks	Single crack width of less than 0.1mm & Spacing of cracks 2m-3m or multiple Hairline crack with no water leakage	Single crack width of between 0.1mm - 0.23mm & Spacing of cracks 1m-2m or multiple cracks width of less than 0.1mm, together with slight water leakage which causes reduction in durability	Single crack width of between 0.23mm - 0.76mm & Spacing of cracks 1m-0.5m or multiple cracks width of less than 0.23mm, together with water leakage, free lime or salt which causes reduction in	Single crack width of greater than 0.76mm & Spacing of cracks < 0.5m or multiple cracks width of less than 0.76mm, together with water leakage, free lime or salt which causes the bridge elements not to support & transfer the load

				loading capacity	
Peel Off	Very small peel off less than 25cm²	Small range of peel off between 25cm²-200cm² due to external forces	Wide range of peel off between 200cm²-760cm² due to rebar corrosion which causes reduction in durability	Serious peel off between 760cm²-1000cm² which causes reduction in loading capacity	Serious peel off greater than 2200cm² which couses concrete falling down
Rebar Exposure	If there is no rebar exposure	Partial rebar exposure between 0cm²-400cm² without corrosion	Partial rebar exposure between 400cm²-1000cm² with corrosion which causes reduction in durability	Serious and wide range of rebar exposure between 1000cm²-1700cm² together with corrosion which causes a reduction in loading capacity	Serious and wide range of rebar exposure greater than 1700cm² together with corrosion which causes a concrete falling down
Honeycomb	Very small Honeycomb less than 100cm²	Honeycomb between 100cm²-400cm² Which affects the durability	Honeycomb between 400cm²-1000cm² With Seriously corroded rebar	Honeycomb between 1000cm²-1700cm² With seriously corroded rebar, which causes a reduction in loading capacity	Honeycomb greater than 1700cm² with very serious damage to the rebar, which causes the closure of the bridge
Void	Very small Void less than 33cm³	Wide range of voids between 33cm³-600cm³ without water leakage	Voids between 600cm³-800cm³ with serious water leakage	Voids between 800cm³-1150cm³ With serious and continuous water leakage	Voids greater then 1150cm³ With serious and continuous water leakage, multiple voids volume, which causes the closure of the bridge
Water Leakage	Very small Water Leakage less than 100cm²	Localized or partial water leakage between 100cm²-400cm²	Serious and wide range of water leakage through cracks or voids between 400cm²-1000cm²	Serious and wide range of water leakage between 1000cm²-2130cm² through cracks or voids which may progress	Serious and wide range of water leakage greater than 2130cm² through cracks or voids which may progress and cause a reduction in loading capacity, together with leaching free lime or salt
End Block Damage (Prestressed Concrete Bridge)	None to Hairline Cracks	Spot cracking width of less than 0.1mm	Partial cracking width of between 0.1mm - 0.23mm which causes reduction in anchorage	Serious and wide range of cracking between 0.23mm - 0.76mm which causes reduction in anchorage	Outstanding cracking greater than 0.76mm on the main end block member, which causes loss of anchoring functions
End Bearing Plate Damage (Prestressed Concrete Bridge)	If there is no broken or corrosion	Partial corrosion between 0cm²-50cm²	End bearing plates are partially broken or corroded which causes reduction in anchorage, between 50cm²-100cm²	Serious and wide range of broken or corroded End bearing plates which causes reduction in anchorage between, 100cm²-200cm²	End bearing plates are broken in wide range greater than 200cm² which causes loses of anchoring functions
Drainage Pipe-Damage	If there is no Pipe-Damage	Locally damaged pipe between 0%-7.5% of the whole pipe, which causes negative effects to other bridge elements	reduces durability of other bridge elements (results in corrosion of metal components or rebar, between 7.5%-20% of the whole pipe	causes heavy problem to others by falling down, between 20%-50% of the whole pipe	the drainage pipes are no more functional, greater than 50% of the whole pipe
Drainage Pipe Blocked	If there is no Blocked	Slight blockage between 0%-7.5% of the whole pipe	Causes standing water during rainfall, effecting on traffic, between 7.5%-20% of the whole pipe	causes serious hindrance in safety to daily traffic and traffic interruption during and after rain, between 20%-50% of the whole pipe	the drainage pipes are no more functional, greater than 50% of the whole pipe
Drainage Pipe Inlet-Damage	If there is no Inlet-Damage	Slight damage between 0%-7.5% of the whole pipe	Reduces drainage function, between 7.5%-20% of the whole pipe	Causes a hindrance to traffic, between 20%-50% of the whole pipe	the drainage pipes are no more functional, greater than 50% of the whole pipe
Pier, Abutment, Wing wall and Foundation Displacement	Very small displacement less than 3.3mm which causes no negative effect	Slight displacement between 3.3mm 13.75mm which Causes no negative effect	Displacement between 13.75mm 31.25mm Causes reduces stability	Displacement between 31.25mm-50mm which may progress and cause reduce stability	Displacement greater than 50mm which may progress and cause Pier, Abutment, Wing wall and Foundation failure
Scour	If there is no scour	Minor scouring to element in river is suspected	Foundation is exposed up to the top of footing or caisson, which may progress and cause a reduction in stability	Foundation is exposed in depth from the top of footing, caisson or design datum level for pile bent, which may progress and cause a serious reduction in stability of foundation	Foundation is exposed in depth from the top of footing, caisson or design datum level for pile bent, which may progress and cause bridge failure
Embankment Depression	If there is no embankment depression	Slight depression with mean difference is less than 13.75 mm in elevation.	Serious depression with mean difference is between 13.75mm-31.25mm in elevation, which may progress and cause a hazard to the bridge and track structure	Outstanding crack or depression with mean difference is between 31.25mm-50mm in elevation, which may progress and cause a hazard to the bridge and track structure	Outstanding crack or depression with mean difference is greater than 50 mm in elevation, which may progress and cause a hazard to the bridge and track structure

Main - Damage for Bearing	If there is no Main - Damage	Spot cracking, corrosion or swelling of main element, less than 5% of the whole bearing	Partial cracking, corrosion or swelling of main element, between 5%-10% of the whole bearing	Outstanding damage, such as cracking on the main bearing member, which affects the loading capacity on metal bearing, between 10%-20% of the whole bearing	Outstanding damage, such as cracking on the main bearing member, which affects the load transfer system, greater than 20% of whole bearing
Parts Missing for Bearing	If there is no Parts Missing	Slight damage, less than 5% of the whole bearing	Partial cracking, incline or swelling on the secondary elements, between 5%-10% of the whole bearing	Secondary elements, such as stopper, anti- lift devices, are broken which reduces bearing function on metal bearing, between 10%-20% of the whole bearing	Secondary elements, such as stopper, anti- lift devices, are broken which causes failure of bearing function on metal bearing, greater than 20% of whole bearing
Anchor Damage for Bearing	If there is no Anchor Damage	Partial corrosion, less than 5% of the whole bearing	Anchor blots are partially broken or corroded on metal bearing, between 5%-10% of the whole bearing	Anchor bolts are broken in wide range, between 10%-20% of the whole bearing	Anchor bolts are broken in wide range which loses anchoring functions on metal bearing, greater than 20% of whole bearing
Bed-Damage for Bearing	If there is no Bed-Damage	Partial cracking or spalling, excessive accumulation of dirt and debris on bearing beds, less than 5% of the whole bearing	Wide range cracking or spalling, between 5%-10% of the whole bearing	Major splitting of bearing block, which loses bearing function on high block type bed, between 10%-20% of the whole bearing	Major splitting of bearing block, which loses bearing function on high block type bed and fail to transfer load, greater than 20% of whole bearing
Unusual Movement for Bearing	If there is no Unusual Movement	Slight unusual clearance, less than 5% of the whole bearing	Unusual clearance, which reduces rotating of sliding function, between 5%-10% of the whole bearing	Excessive and unusual clearance from the original place, between 10%-20% of the whole bearing	Excessive and unusual clearance from the original place which causes a hazard for the track structure, greater than 20% of whole bearing
Water Leakage for Expansion Joint	If there is no Water Leakage	Slight water leakage	Slight water leakage, which causes leakage trace on slab, beam or piers	Water leakage, which accumulates debris dirt on pier caps, affects seriously and causes a reduction in durability to other bridge components.	Excessive leakage, which causes hindrance to other bridge components.
Deformation for Expansion Joint	If there is no Deformation	Slight Hollow or swelling	Slight Hollow or swelling which has an effect on smooth driving	Hollow or swelling which has an effect on safe driving	Deformation or cracking to joint elements, which causes a hindrance to traffic on metal joints
Peel Off for Expansion Joint	If there is no Peel Off	Seal material is partially taken away	Seal material is partially taken away which causes negative effect on smooth riding	Sealing material is taken away, which has an effect on water leakage and smooth driving	Serious peel off of joint elements which causes a hindrance to safe traffic
Missing for Expansion Joint	If there is no Missing	Minor Joint components partially missing	Minor Joint components partially missing which causes negative effect on smooth riding	Joint components missing which has an effect on smooth driving	Major components missing to joints, which may progress and causes a hindrance to safe train traffic
Defect Rating for Steel Girder					
Deformation / Deflection	If there is no Deformation / Deflection	Partial deformation less than 1mm on secondary members	Partial deformation between 1mm-2mm on primary members	Outstanding deformation between 2mm-5mm, which affects the loading capacity due to buckling or partial yielding	Outstanding deformation greater than 5mm, which affects the loading capacity due to buckling or partial yielding
Cracking	If there is no Cracking	Spot cracking less than 1mm on secondary members	Spot cracking between 1mm-2mm on primary bridge components	Cracking between 2mm-5mm on primary members, especially in welded parts	Outstanding cracking greater than 5mm on primary members, especially in welded parts
Corrosion	If there is no Corrosion	Partial corrosion less than 400cm² on secondary members	Partial corrosion between 400cm²-1000cm² on primary member	Major corrosion between 1000cm²-3000cm², which affects the loading capacity by reducing cross sectional area on primary member	Major corrosion greater than 3000cm², which affects the loading capacity by reducing cross sectional area on primary member
Wearing	If there is no Wearing	Partial wearing less than 400cm² which affects the durability of secondary members	Partial wearing between 400cm²-1000cm² which affects the durability of primary members	Major wearing between1000cm²-3000cm² in almost all range on bridge components, which affects the durability of primary and secondary members	Major wearing greater than 3000cm² in almost all range on bridge components, which affects the durability of primary and secondary members
Bolt Missing	If there is no Bolt Missing	Missing or loosening of 1 bolt on joints	Missing bolt 1-3 on a secondary member joints	Missing bolt 3-6 on a primary member joints	Missing bolt greater than 6 on a primary member joints

Paint Peel off	If there is no Paint Peel off	Paint Peel less than 400cm² off which affects the steel durability, but without corrosion	Paint Peel off between 400cm²-1500cm² which affects the steel durability, together with corrosion	Peel off of paint almost all of area, which affects the steel durability, together with serious corrosion	Peel off of paint almost all of area, which affects the steel durability, together with serious corrosion
Defect Rating for Track Structure					
Gauge, Mm	If it is 0	Less than 6 or -2	Between 6-7 or Between -2-(-4)	Between 6-9 or Between -2-(-4)	Greater than 9 or Greater than -4
Level, Mm	If it is 0	Less than 4	Between 4-6	Between 6-10	Greater than 10
High-low, Mm	If it is 0	Less than 4	Between 4-6	Between 6-10	Greater than 10
Direction, Mm	If it is 0	Less than 4	Between 4-6	Between 6-10	Greater than 10
Twist of track (Easement curve), Mm	If it is 0	Less than 4	Between 4-5	Between 5-7	Greater than 7
Twist of track (Straight & Circular curve), Mm	If it is 0	Less than 4	Between 4-6	Between 6-9	Greater than 9
Head abrasion, Mm	If it is 0		Less than12	Between 12-18.5	Greater than 18.5
Peeling or chip falling at the rail end or top, Mm	If it is 0		Length of >15 and Depth of >4	Length of >30and Depth of >8	
Rail surface scratch, Mm	If it is 0		Depth of >1mm	Depth of >2mm	
Low rail joint, Mm	If it is 0		Depth of >3mm	Depth of >3.5mm	
Wave abrasion, Mm	If it is 0			Trough of more than 0.5mm	
Rail corrosion, Mm	If it is 0			After rust removal, rail base thickness is < 5mm or rail web thickness is < 8mm	
Rail surface crack (Yes / No)	If it is No			If it is Yes	
Rail internal crack (Yes / No)	If it is No			If it is Yes	
Rail deformation (Yes / No)	If it is No			If it is Yes	

4.2.4 Railway Bridge Inspection Formats

The first inspection format is for Major Inspection and the second inspection format is for Regular Inspection.

RAILWAY BRIDGE INSPECTION FORMAT

For Major Inspection

RAILWAY LINE NAME	RAILWAY SUBLINE NAME	BRIDGE NAME	BRIDGE No

IT. NO	BRIDGE PARTS	DAMAGE TYPE	DAMAGE QNTY BY RANK				
	Super structure		New	Minor	Moderate	Sever	Failed
1	Deck Slab	Cracking , Mt					
		Peel Off , Mt2					
		Rebar Exposure, Mt2					
		Honeycomb , Mt2					
		Void , Mt2					
		Water Leakage , Mt2					
2	Concrete Girder	Cracking ,Mt					
		Peel Off , Mt2					
		Rebar Exposure, Mt2					
		Honeycomb ,Mt2					
		Void , Mt2					
		Water Leakage , Mt2					
		End Block Damage (Prestressed Concrete Bridge)					
		End Bearing Plate Damage (Prestressed Concrete Bridge)					
3	Steel Girder	Deformation, Mt					
		Cracking , Mt					
		Corrosion , Mt2					
		Wearing , Mt2					
		Bolt Missing , Each					
		Paint Peel off ,Mt2					
4	Bearing	Main Damage, Each					
		Parts missing, Each					
		Anchor Damage, Each					
		Bed Damage, each					
		Unusual movement, Each					

IT. NO	BRIDGE PARTS	DAMAGE TYPE	DAMAGE QNTY BY RANK				
	Sub Structure & Foundation		New	Minor	Moderate	Sever	Failed
5	Pier and Foundation	Cracking ,Mt					
		Peel Off ,Mt2					
		Rebar Exposure , Mt2					
		Honeycomb , Mt2					
		Void ,Mt2					
		Water Leakage , Mt2					
		Displacement Mm					
		Scour, Mt2					
6	Abutment and Wingwall	Cracking, Mt					
		Peel Off / Stone deterioration, Mt2					
		Rebar Exposure , Mt2					
		Honeycomb , Mt2					
		Void ,Mt2					
		Water Leakage , Mt2					
		Displacement / Bulging ,Mt2					
		Scour , Mt2					
7	Embankment	Depression , Mt2					
		Erosion , Mt2					

IT. NO	BRIDGE PARTS	DAMAGE TYPE	DAMAGE QNTY BY RANK				
	Track Structure & Ancillaries		New	Minor	Moderate	Sever	Failed
8	Track Structure	Gauge, Mm					
		Level, Mm					
		High-low, Mm					
		Direction, Mm					
		Twist of track (Easement curve), Mm					
		Twist of track (Straight & Circular curve), Mm					
		Head abrasion, Mm					
		Peeling or chip falling at the rail end or top, Mm					
		Rail surface scratch, Mm					
		Low rail joint, Mm					
		Wave abrasion, Mm					
		Rail corrosion, Mm					
		Rail surface crack (Yes / No)					
		Rail internal crack (Yes / No)					
		Rail deformation (Yes / No)					
9	Kerb & Railing	Cracking, Mt					
		Peel Off, Mt2					
		Rebar Exposure , Mt2					
		Deformation, Mt					
		Corrosion, Mt					
		Missing, Each					
10	Expansion Joint	Water Leakage, Mt					
		Deformation, Mt					
		Peel Off, Mt					
		Missing, Mt					
11	Drainage	Pipe Damage , Each					
		Blocked, Each					
		Inlet Damage, each					

General Comment:

Hydrology defects	
Water Way adequacy (Over flooding, Siltation, Scouring,…)	
Yes	No

Inspector Name:_____

Signature:_____

Date:_____

Figure 4-5: Railway Bridge Inspection for Major Inspection

RAILWAY BRIDGE INSPECTION FORMAT

For Regular Inspection

ROUTE NAME	SUBROUTE NAME	BRIDGE NAME	BRIDGE No

IT. NO	BRIDGE PARTS	DAMAGE TYPE	DEFECT SEVERITY					IT. NO	BRIDGE PARTS	DAMAGE TYPE	DAMAGE QNTY BY RANK					IT. NO	BRIDGE PARTS	DAMAGE TYPE	DAMAGE QNTY BY RANK				
	Super structure		New	Minor	Moderate	Sever	Failed		Sub Structure & Foundation		New	Minor	Moderate	Sever	Failed		Track Structure & Ancillaries		New	Minor	Moderate	Sever	Failed
1	Deck Slab	Cracking						5	Pier and Foundation	Cracking						8	Track Structure	Gauge					
		Peel Off								Peel Off								Level					
		Rebar Exposure								Rebar Exposure								High-low					
		Honeycomb								Honeycomb								Direction					
		Void								Void								Twist of track (Easement curve)					
		Water Leakage								Water Leakage								Twist of track (Straight & Circular curve)					
2	Concrete Girder	Cracking								Displacement								Head abrasion					
		Peel Off								Scour								Peeling or chip falling at the rail end or top					
		Rebar Exposure						6	Abutment and Wingwall	Cracking								Rail surface scratch					
		Honeycomb								Peel Off / Stone deterioration								Low rail joint					
		Void								Rebar Exposure								Wave abrasion					
		Water Leakage								Honeycomb								Rail corrosion					
		End Block Damage (Prestressed Concrete Bridge)								Void								Rail surface crack					
		End Bearing Plate Damage (Prestressed Concrete Bridge)								Water Leakage								Rail internal crack					
3	Steel Girder	Deformation								Displacement / Bulging								Rail deformation					
		Cracking								Scour						9	Kerb & Railing	Cracking					
		Corrosion						7	Embankment	Depression								Peel Off					
		Wearing								Erosion								Rebar Exposure					
		Bolt Missing																Deformation					
		Paint Peel off																Corrosion					
4	Bearing	Main Damage																Missing					
		Parts missing														10	Expansion Joint	Water Leakage					
		Anchor Damage																Deformation					
		Bed Damage																Peel Off					
		Unusual movement																Missing					
																11	Drainage	Pipe Damage					
																		Blocked					
																		Inlet Damage					

General Comment:

Hydrology defects	
Water Way adequacy (Over flooding, Siltation, Scouring,...)	
Yes	No

Inspector Name:_____

Signature:_____

Date:_____

Figure 4-6: Railway Bridge Inspection Format for Regular Inspection

It is mandatory to know that, any data which is going to be filled in the standard forms will lead to final decision on what measure is needed to take. Therefore, inspectors have large responsibility to check again and again what they filled in the forms.

Possible recommendation of the inspector team after inspecting the existing bridges with the following findings can be:

Table 4-5: Possible recommendation of the inspector for existing bridges with the following defects

Bridge Defects	Possible Recommendation of the Inspector	Remark
Scour at pier and /or abutment	Rehabilitation	based on the damage level
	Preventive Maintenance	
	Corrective Maintenance	
Overtopping	Replacement	if hydrological inadequate
	Preventive Maintenance	if there is siltation
	Corrective Maintenance	
Road and post crushing	Replacement	if it is not functional
	Rehabilitation	based on the damage level
	Preventive Maintenance	
	Corrective Maintenance	
Pot holes with Rebar exposure in Deck	Rehabilitation	
	Preventive Maintenance	
	Corrective Maintenance	
Water Leakage on Deck	Rehabilitation	
	Preventive Maintenance	
	Corrective Maintenance	
Shear Crack on Girder	Rehabilitation	if the crack is hairline and crack extent (length) is very small
	Preventive maintenance	
	Corrective Maintenance	
	Replacement	crack is wide (≥ 5mm) and the crack extent is very wide
Flexural Crack	Rehabilitation	if the crack is hairline and crack extent (length) is very small
	Preventive maintenance	
	Corrective Maintenance	
	Replacement	crack is wide (≥ 5mm) and the crack extent is very wide
Foundation settlement	Replacement	

4.2.5 Railway Bridge Damage Weight

The main purpose of weighting bridge defects is to determine the condition of the bridges like very good, good, fair, bad or fail. Beside this, determination of the bridge condition is an importance input to make critical decision like replacing the bridges.

Summary of Railway Bridge Damage Weight is presented in **Appendix H**.

4.3 Procedures of Railway Bridge Inventory and Inspection

4.3.1 Procedures of Inventory and Inspection

The followings activities are included in Planning and scheduling:

A/ Document Review:

- "As-Built" bridge plans and shop drawings, where available
- Maintenance and Repair Records/Correspondence
- Previous inspection reports
- Correspondence pertinent to any required work or work completed

B/ Pre-Inspection: helps

- **To** determine access requirements
- observing the overall condition of the bridge to gage time requirements
- To make the inspection team aware of more than one structure in a close proximity that may require similar special access equipment.
- to see that there is no construction activity in the area that might interfere with access and protection of traffic patterns

C/ Coordination of Access and Equipment Needs: enable the inspector's

- To coordinate the inspection equipment's
- To coordinate access requirements necessary for to proper performing the inspection
- To decide railroad flag protection needed or not
- To have weather Town Permit be required or not
- To have assistance traffic control or not

D/ Weather Considerations: This can permit a more thorough and comfortable inspection.

Prior to commencing site inspections, the inspector shall ensure that he has all the relevant documentation, inspection equipment and safety equipment to carry out the inspection.

After considering the above requirements the following sequence of inspection is suggested for most bridges:

1. Arrive at the target bridge
2. Park at the safe space with necessary traffic safety measures
3. Check the location data and name of the bridge
4. Check the GPS indication
5. Examine the entire track way condition from the abutment side(s)
6. Inspect the bridge approaches and embankments (immediate regions placed on both sides of a railroad bridge, typically within (3-6 m) from the bridge back walls) for:
    - ❖ Running surfaces for settlement, depressions, cracking and other deterioration;
    - ❖ Embankments for erosion, scour and slope protection
    - ❖ Track drainage for accumulations of debris and growth inside drains, channels, inlet and outlet and
    - ❖ Track and bridge drainage for scour, especially at track drainage
7. Examine the expansion joint
8. Examine the track
    - ❖ Gage, level and alignment;
    - ❖ Examine rail defects like corrosion, abrasion, crack, bolt missing etc.;
    - ❖ Examine defects on rail fasteners, sleepers and ballast and
9. Inspect the deck from the top
10. Examine the parapet and railing
11. Examine the drainage inlets
12. Examine the surrounding land condition
13. Move down to underneath the bridge (channel, opening)
14. Inspect the underside of the deck
15. Inspect the beams/superstructure
    - ❖ defects such as spalling, cracking, staining, corrosion, excessive vibration, etc;
    - ❖ bearing plate and anchorage
16. Inspect the abutments, pier and wing walls
    - ❖ Cracking, splitting, distortion, bulging, excessive movement, etc;
    - ❖ Inclination and settlement;
    - ❖ Weep holes in abutments and retaining walls for free drainage
17. Examine the bearing(s) at the abutment(s)
18. Examine the piers

19. Examine the bearing(s) at the piers
20. Examine the high water level
21. Inspect the waterway (river bank, sedimentation)
22. Take the pictures of defects/damages
23. Check all the inspection records are correctly filled in the standard form
24. Check all the inspection equipment's collected
25. Leave the bridge

4.3.2 Photograph guidelines

Photographs are essential for understanding site information of the bridge, the nature of a defect and tracking how the defect changes over time.

The following general descriptive photos should be taken:

- Appearance of bridge from both approaches
- An elevation (upstream and downstream) of the bridge.

Further photographs of the following items, where present, are also required:

- Identification and description of any significant problem areas
- New repairs
- Strengthening works
- Widening detail
- Overall view of the underside of a typical span
- Expansion joint (typical)
- Bearing (typical)
- Bridge and approach guardrail (typical)
- Wing wall and Pier detail (typical)
- Accident
- Services / utility installations on the bridge
- Substructure protection
- Surrounding land condition

All inspection photographs shall be taken using digital cameras.

Sufficient photographs should be taken to show the full extent of the deteriorated area and its location along the member.

When taking pictures of deterioration, cracks and other deficiencies, check the photo in the LCD display to make sure the item the Inspector are trying to photograph is depicted. If the deficiency does not show up in the photo, retake the photo.

4.4 Facilities for Railway Bridge Inventory and Inspection

The following facilities are needed for bridge inventory and inspections:

- Bridge Inspection Guideline and Different Inventory and Inspection format.
- Furnished office for Bridge Inspection Personnel's,
- Computer, Printer and Other office tools,
- Inspector's safety (protective) equipment's ;
- Different measuring Equipment's and
- Inventory and Inspection Vehicle and Crane.

The following table includes different documents, measuring and safety equipment's which are used during Bridge Inventory and Inspection.

Table 4-6: Documents, Measuring and Safety equipment's for Bridge Inventory and Inspection

SR	INSTRUMENTS	PURPOSE
1	Inspection and Inventory report formats, notebook and clipboard with pencil, pen	To record findings
2	As-built Drawings	To review the available information contained in the bridge file
3	high visibility vest, safety boots and waterproof boots, gloves, both leather and plastic, Helmet, Reflector Jacket at the back should be written `Bridge Inspection`	Personal protective equipment
4	first aid kit	In case of accidents for emergency works
5	Signage	For train traffic management purposes as required
6	GPS unit	To read location / coordinate
7	wire brush	To clean
8	radio unit and mobile phone	To communicate
9	50M Steel tape	For taking measurements such as clear span, overall length of girder, etc.
10	3.5M Pocket Tape	To measure bridge dimensions and defects
11	Straight edge (1M Long)	For checking deformation, distortion, buckling and bulging of structure
12	Crack Gauge (0.1 to 5mm)	For measurement width of cracks and cavity
13	Caliper	For measurement width of cracks
14	Nylon cord or Piano wire with clamp and 2 nos. 10kg. weight	For measuring camber of PSC girder.
15	15 cm steel scale	For measuring depth of spalled concrete and gap between parts.
16	Mirror (10 x 15 Cm)	For inspecting parts in any awkward location by reflection method and to lit object in dark location by directing sun rays.
17	Magnifying glass (100mm dia)	For identifying very fine cracks in member/ welds which may not be visible for naked eyes.
18	Torch light (5 cell)/ Flash light	Used along with mirror for identification of fine cracks in dark locations.
19	Plumb bob	For checking verticality of member , pier and abutment etc.
20	Thermometer	For recording temperature at the time of measuring rail joint gap, camber and for purpose of setting bearings at desired inclination.
21	Spirit level	For checking cross level of track on bridge or bed block. Also for setting of girders on bearing.
22	Information Board	Min 50x50 cm to write general bridge data
23	Chalk marker, plaster of Paris, Red Paint, Plain glass	To mark the cracks on concrete structure and make tel-tale for observing crack.
24	Binoculars	For inspection of bridge components which are at inaccessible location tall piers, arches in viaducts, etc. prior to closer examination.
25	Camera with flash	For taking photograph of cracks, spalled concrete or any distressed portion for clarity and record.
26	Pocket knife	For removing scaled or weathered surface of concrete for inspection.
27	Schmidt's rebound hammer for concrete	For assessing the strength of concrete structure for soundness as non-destructive test method.
28	Concrete cover meter (R meter)	For assessing the cover availability to reinforcement in existing concrete structure or diameter of steel bar or spacing.
29	Scaffolding/Ladder	To provide close accessibility to structure for inspection of girder, sub structure etc.

During Major Inspection a significant portion of the railroad bridge inspections are performed without train loads, since many of the railroad bridges within the railroad network are not otherwise accessible. In these cases, railroads perform their inspections by using high-rail cars. High-rail cars are vehicles equipped to ride both on highway and rail environments by switching their trucking equipment. High-rail cars allow access to bridges. Once bridge inspectors reach bridges via high-rail cars, railroads make use of small cranes to bring bridge inspectors under the bridge deck and other areas that need to be inspected.

4.5 Types of Bridge Inspection Investigation

The methods of Inspection in this Guideline are:

Visual Inspection: is made to determine the general condition of the structures, identify areas of distress, likely sources of problems and identify the visible defects. All visible defects such as concrete cracking, apparent delamination, concrete spalling, exposed corroding reinforcement etc, need to be recorded in the Inspection Format.

Non-Distractive test / Schmidt's rebound hammer test: is for concrete bridges to assess the strength of concrete structure for soundness as non-destructive test method. Like examining the extent of corrosion, adherence of paint and removing loose disintegrated material during inspection.

4.6 Safety Measures during Inventory and Inspection

Staff involved in bridge inventory and inspection should be familiar with standard document of Labour Proclamation of the Country with respect to Safety, Health and Environment.

Safe inspection vehicle parking should be exercised.

While Inspecting Bridges one should adopt certain safety measures which are listed below:

- Wear suitable dress so that loose end don't get caught ; too-tight a dress may hamper inspectors free movements
- If inspectors normally wear glasses for improving inspector’s eye sight, wear glasses when climbing up or down sub-structures & super structures.
- Keep clothing & shoe free from grease and steel stars or nail etc. which causes slipping.
- Scaffolding or platforms should be free from grease or other slippery substances.
- Scaffolding and working platforms should be adequate strength and be secured against slipping or overturning.
- No shortcut at any cost. Vigil over passing trains
- Keep your trolley and other equipment’s properly so that they should not infringe the track.
- Say no to liquor or any other sedative medicine.

- Follow all operating rules and follow the guide lines while inspecting under any caution order/ block (power/ traffic or both)
- Insist inspector's staff to be very careful while walking moving through footpaths/ any other members.
- No chit, chatting and fun etc. while on Inspection.

4.7 Suggested Personnel Requirements

The following personnel's shall be included in the Railway Bridge Inventory and Inspection.

Asset Management Department Head

In charge of:

- Avail all Railway Bridge Inventory and Inspection related information
- Present General and Detail data and information on Railway Bridge Inventory and Inspection activities
- Coordinates Technical Assistance and Capacity building works
- Propose enhancements in bridge works

Railroad Bridge Coordinator / Team Leader

In charge of:

- Planning work flow, determines priorities, coordinate the inventory and inspection task
- Initiate emergency inspection up on occurrence
- Reviews the inspection data's
- Acts as liaison with operating units, agencies, and outside officials regarding policies

Railroad Bridge Engineer

In charge of:

- Acts as Leader in field bridge inspection team
- Inspection of bridges based on Guideline
- Reviews bridge plans and previous inspection reports
- Prepares inspection notes and sketches
- Follow bridge inspection equipment operates as required
- Evaluates seriousness of bridge defects
- Perform emergency inspection
- Propose maintenance type, design repairs to defects
- Prepare reports on inventory and inspections

Railroad Track Engineer

In charge of:

- Work closely with Railway Bridge Engineer in railway track over the bridge
- Inspection of track line based on Guideline
- Prepares inspection notes and sketches
- Evaluates seriousness of railway track defects
- Ensures onsite train traffic protection during inspection
- Perform emergency inspection
- Propose maintenance type, design repairs to defects
- Prepare reports on inventory and inspections
- Develops and maintains maximum civil train speeds
- Maintains historical maintenance records and databases

Railroad Bridge Inspector

In charge of:

- Assisting a Railroad Bridge Engineer
- Reach all parts of the bridge to be inspected
- Accurately measure, record and report Defects to the Bridge Engineer
- Check availability of all equipment at inspection site
- Operates bridge inspection equipment as required
- Perform emergency inspection with Bridge Engineer

Assistant Railroad Bridge Inspector

In charge of:

- Assist the Bridge Inspector during inspection
- Reach all parts of the bridge to be inspected
- Operates bridge inspection equipment as required
- Perform emergency inspection with Bridge Inspector

Figure 4-7: Suggested Personnel Requirements for Railway Bridge Inventory and Inspection

All personnel should be familiar with the Department's "Employee Handbook." The handbook is available to assist all Personnel's in Bridge Inspection to become more aware of their role, function, and authority, and to assist them in dealing with common types of employee problems.

All personnel's should satisfy the educational and physical qualifications criteria which shall be setted by the AALRT or ERC and shall be formally certified by ERC and AALRT. All personnel's should be trained regularly (semiannually or annually) by ERC or AALRT.

4.8 Reporting Inventory and Inspection Findings

The bridge inspection report is a complete record of the bridge inspection. The reports including completed standard inventory and inspection forms, field notes, sketches, supporting photographs and miscellaneous notes are submitted either in a digital format or in a hard copy format bound using a suitable, removable clip or binding.

The Inspection Report should consist of the following general sections:

- Executive Summary;
- Introduction;
- Detailed investigation results;
- Discussion of investigation results;
- Summary of current condition;
- Conclusions;
- Recommended remedial actions for defects identified and
- Recommendations on further testing and schedule, if required;

When a critical defect affecting the safety of the bridge structure or the safety of the traveling public is found during an inspection, it is imperative that the Bridge Engineer is responsible to inform the situation immediately. Some examples of critical defects include:

- Distress in primary members;
- Extensive Scour at or under a substructure;
- Substructure movement or distress;
- Suspected cracks in fracture critical members;
- Any situation where the structural integrity of the bridge is in question and

- Any situation that poses an immediate hazard to traffic on or under the bridge due to loose or broken components, severe deterioration of the bridge riding surface or materials that can drop to occupied areas below the bridge.

Numbering of railroad bridge elements is based on the direction of increasing milepost. Numbering advances from the beginning to the end of the bridge, progressing in the direction of increasing milepost. Girders and other longitudinal members are numbered from left to right facing the direction of increasing milepost.

Use of the Bridge Inspection Files

Since it is extremely important that the information contained in the inspection files be available in an emergency situation, the removal of the file from its assigned location or removal of portions of the individual file must be discouraged and monitored carefully.

To monitor the files, the following shall be applied:

- No original file or portion thereof may be removed from the files without special approval.
- Files shall be kept in chronological order, with all contents facing forward.
- If it is necessary to separate or unbind any part of the file for making copies, you are expected to return this material to its original form and order.
- When a folder is removed from a file, a reference card shall be filled out and inserted in place of the file.
- File folders in poor condition shall be given to the designated staff member for repair or replacement.

The process of distribution, review and evaluation of inspection reports shall be Field inspection by Bridge Engineer, Bridge Inspectors and Track Engineer findings are reported to the Bridge Coordinator/ Team Leader to review the findings. Again the Bridge Coordinator submits to Asset Management Department Head where decision would be provided based on the findings of the inspection.

5. CONCLUSION AND RECOMMENDATION

5.1 Conclusion

In conclusion, from literature review, questionnaire, interview and observation the required data's were collected and analyzed. The results obtained in this processes have been discussed and presented in the previous chapter. Therefore, based on the results from the analysis, the following major conclusions have been drown and summarized in accordance with the objectives of the research.

The results of the study demonstrated that the level a high degree of accurate Bridge Database is only maintained if the bridge Inventory and Inspection is carried out using well-established guideline. If the bridge Inventory and Inspection tasks are not performed for all bridges without having a well-established guideline, frequent collapse would occur at the same time in many parts of the county and would provoke social and political chaos.

The study also prepare railway bridge inventory format. This format is developed to record and to have a unified database for bridges. It contains information regarding Type of Inventory, Bridge Location, and General Information of the bridge, Track Structure, Super Structure, Substructure and Foundation and Ancillaries.

The study has identified four types of Railway Bridge Inspection based on their purposes and frequencies. These include Initial Inspection, Regular Inspection, Major Inspection and Emergency Inspections.

Initial Inspection is carried out to obtain detailed general information of the bridge that includes bridge dimensions and member sizes, photographs and member-specific data of any deterioration. It is the first inspection of a bridge as it becomes a part of a bridge file. This inspection is carried out only once, unless changes have been made on the bridge. Initial Inspection shall be carried out 3 months after the bridge owners handover the bridge assets.

Regular Inspection is carried out to check on the overall safety and performance of the structure and the identification of any minor and major accident damage or incident and any obvious failure of structural components. The method of inspection is visual and carried out in every month.

Major Inspection is carried out to assess and record the physical condition of structural components of the bridge and to ensure that the bridge is adequate to safely carry the intended loads. In this inspection quantitative data on structural components are collected for use in engineering analyses and deterioration models. The method of inspection is detail visual and Schmidt's rebound hammer for concrete to assess soundness and carried out in a once in five years.

Emergency Inspections is carried to evaluate damage to a bridge caused by flood, earthquake, derailment, collision or other unusual occurrences, to provide information on structural safety and safe train traffic condition and to judge necessity of emergency measures. This inspection is carried out immediately upon occurrence.

Further, the study also addressed how rating / ranking is made based on severity of Railway Bridge defects as new condition, minor, moderate, sever and failed condition. Due to the rating system, the inspection reflects the specific conditions and desirable interventions. With respect to this the rating of each bridge defects can be prepared.

Likewise, the weights of bridge defects are categorized in to no significant important, minor, moderate, major and critical. The weight / significance of each bridge defects on each bridge components are weighted out of the whole bridge components and defects. The main purpose of weighting bridge defects is to determine the condition of the bridges like good, fair, bad or fail.

Possible recommendation of the Inspector for the existing bridges based of the finding of the site inspection is also included in this study.

The study also prepare railway bridge inspection format for regular and major inspections. Any data which is going to be filled in the standard forms will lead to final decision on what measure is needed to take. The regular inspection format enables the bridge inspectors to record the overall safety and performance of the structure and identify any defect as new condition, minor, moderate, severs and failed. On the other hand, the major inspection format enables the bridge inspectors to record types of defects, severity of defects and extent of the defects.

The standard procedure of railway bridge inventory and inspection is also discussed in this study. This portion discuss Planning and scheduling, Document Review, Pre-Inspection, Coordination of Access and Equipment Needs, Weather Considerations and Standard Procedure of Inspection. The main purpose of this part was to promote the effective and efficient inventory and inspection tasks with respect to limited manpower and budgetary constraints.

Beside the inventory and inspection information that is recorded on the inventory and inspection formats, Photographs are used to provide site information of the bridge and to support comments on the condition of the bridge reported by the Inspector. With respect to this, this study discus general photograph requirements and requirement for additional photographs.

The other one is facility required for Railway Bridge Inventory and Inspection. With respect to this, this study comes up with different equipment's that is required for bridge inventory and inspection. These are furnished office for bridge inspection personnel's, computer, printer and other office tools, inspection formats, guidelines and different bridge inspection manuals, High-rail cars (to ride both on highway and rail environments), inspector's safety (protective) equipment's and different measuring Equipment's.

A type of bridge inspection investigation techniques for regular inspection is based on visual investigation from ground level. On the hand, the method of inspection for major inspection is close and detail visual investigation and non-destructive test (Schmidt's rebound hammer to check soundness of concrete).

Moreover, this study also includes safety measures during inventory and inspection. These include, know potential danger places like sliding embankments, very fast train corridor and work in electrified zones. Wearing personnel protective, train traffic management, parking at a safe place are also discussed in this study.

In assessing personnel's required for bridge inventory and inspection, this study find out the Bridge Inspection Coordinator / Team Leader, Bridge Engineer, Bridge Inspector, Assistant Bridge Inspectors, and Track Engineer are personnel's involved bridge inventory and inspection. The responsibilities of each person are also included.

Finally, how to report and how to use inventory and inspection findings and reports are included in this study. The bridge inventory and inspection report is a complete record of the bridge and final decision like maintenance, rehabilitation or replacement on the bridge is made based on this report.

5.2 Recommendation

The following recommendations have been drawn from the result of this study.

- The volume of railway bridge stock will increase in our country as the railroad networks enter in to operations. Therefore, perform railway bridge inventory and inspection immediately after handovering the railway bridges. Otherwise it would be difficult after missing some bridge documents.
- Provide extensive training for bridge inspectors.
- Prepare organizational safety rule for bridge inspections.
- Fulfill all the required equipment's for bridge inspection.
- Develop bridge inspection department's "Employee Handbook".
- Work on bridge inventory and inspection knowledge transfer from Chinese.
- If the bridge inventory and inspection task is difficult for the bridge owners, it is prefer to hire a consulting firm.
- Provide enough fund / budget for bridge asset management tasks.
- Top managements should pay attention for bridge asset management.
- Bridges located at strategic location shall be protected from terrorists by a police force.
- Establishing a systematic bridge database management like Bridge Management Software.
- There should be an Emergency Team who works during emergency breakout like bridge failure.
- There should be an Organizational regulation, Guideline and Central bridge Database for railway bridge inventory, inspection and maintenance.

Future scope of the study

The current study with its own limitation prepares guideline for inventory and inspection of railway bridges. Nevertheless, the following issues should also be considered in the future based on the outcomes of the current study:

- Guideline for inventory and inspection of railway Culverts.
- In this study the bridge inspection investigation techniques for regular and major inspection is based on visual investigation and non-destructive test (Schmidt's rebound hammer to check soundness of concrete) are discussed. But, the same guideline can be prepared for other types of advanced investigation techniques like ultrasonic pulse velocity, corrosion rate measurements, material sampling, Intrusive testing – such as drilling holes and laboratory Investigation.
- Prepare guideline for inventory and inspection of railway track line.
- Prepare maintenance guideline for railway track line.
- Prepare safety guideline during inspection of railway track and bridges.
- Develop software for bridge asset management to handle bridge database.
- A guideline for Determination of Railway Bridge Inspection Interval Using Reliability-Based Bridge Inspection Practices
- A guideline for railway track and bridge emergency.

6. REFERENCES

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Appendix A

Questioner for ERC and AALRT

Addis Ababa University

Addis Ababa Institute of Technology

School of Civil and Environmental Engineering

Railway Stream

Objectives of the Questionnaire

The primary objective of this questioner is to investigate and document Railway Bridge Inventory and Inspection practices by Ethiopian Railway Corporation. This questioner is an important input for the MSc. Thesis in the **preparation of Guideline for Inventory and Inspection of Railway Bridges.**

The main objective of the study is to prepare guideline for inventory and inspection of railway bridges to ensure that a bridge continues to perform its function under acceptable conditions of safety and with minimized cost of maintenance.

The research tries to address the following points:

- Inventory and Inspection formats
- Types and frequency of Inspection
- Procedures and Equipment's for Inventory and Inspection
- Safety Measures during Inventory and Inspection
- Suggested Personnel Requirements
- Reporting Inventory and Inspection Findings
- Forward recommendations which would help the preparation of Inventory and Inspection Guideline for Railway Bridges in Ethiopia.

Dear Respondents

Your response has considerable value in this study, Kindly respond to all questions. It is not required to write your name and the responses you give will be used only for this study and remain confidential. Email address in case you have question is davobon100@gmail.com. Thank you for your cooperation!

General Instruction

- Put **'x'** in the boxes accompanied by various choices, to make your answer.
- You may tick more than one alternative answer wherever necessary.
- For open ended questions write your answer in the space provided.

General Information:

Company Name: _____

Unit / Department: _____

Position/Title: _____

Highest Educational Level: ☐ Certificate ☐ Diploma ☐ BSc ☐ MSc ☐ PhD

Work Experience in year: ☐ < 2 years ☐ 3-5 years ☐ 6-10 years

☐ 11-15 years ☐ > 15 years

Topic # 1: Organizational Structure and Background:

1. Which railway lines are owned by Ethiopian Railway Corporation?

☐ Addis Ababa Light Rail Transit ☐ All Federal Railway Networks ☐ All Railway Networks

2. Who is responsible for inventory, inspection and maintenance of railway bridges in Addis Ababa Light Rail Transit?

☐ Ethiopian Railway Corporation ☐ Addis Ababa Light Rail Transit ☐ Others (please specify) _____

3. Who is responsible for inventory, inspection and maintenance of railway bridges along all Federal Railway Networks?

☐ Ethiopian Railway Corporation ☐ Addis Ababa Light Rail Transit ☐ Others (please specify) _____

4. Is there any Guideline related to inventory & inspection of railway bridges in Ethiopia?

☐ No ☐ Yes. If yes, please specify the Guideline_____

5. Is there any Organizational regulation for railway bridge inventory, inspection and maintenance in your Organization?

☐ No ☐ Yes. If yes, please specify regulations_____

6. Is there any central database to manage railway bridges?

☐ No ☐ Yes

7. What is the total numbers of railway bridges registered in your organization?

Number of railway bridges_____ ☐ Unknown

8. How old are your bridges. What numbers of bridges are?

☐ < 5 Years – No._____ ☐ 5-10 Years – No. _____ ☐ 5-15 Years – No._____

☐ 15-25 Years – No. _____ ☐ >25 Years – No._____ ☐ Unknown

9. What are the types of railway bridges in your organizations?

A/ PRESTRESED CONCRETE

- ☐ PRECAST BOX GIRDER
- ☐ CAST IN PLACE BOX GIRDER
- ☐ PRECAST I - BEAM
- ☐ CAST IN PLACE I - BEAM
- ☐ PRECAST INTEGRAL BEAM AND SLAB
- ☐ CAST IN PLACE INTEGRAL BEAM AND SLAB
- ☐ PRECAST BOX UNITS
- ☐ CAST IN PLACE BOX UNITS
- ☐ PRECAST T - BEAMS
- ☐ CAST IN PLACE T - BEAMS
- ☐ PRECAST SLAB PANELS
- ☐ CAST IN PLACE SLAB PANELS
- ☐ RIGID FRAME BRIDGE
- ☐ EXTRADOSED BRIDGE

B/ REINFORCED CONCRETE

- ☐ BOX GIRDER
- ☐ DECK GIRDER
- ☐ ARCH
- ☐ PRECAST BOX UNITS
- ☐ CAST IN PLACE BOX UNITS
- ☐ SLAB

C/ STEEL CONCRETE COMPOSITE

- ☐ BOX GIRDER
- ☐ STEEL BEAMS & CONCRETE DECK

D/ STEEL

- ☐ I-BEAM
- ☐ STEEL ARCH
- ☐ TRUSS

If the types of bridges not included in the above list, please specify_____

_____

_____

Topic # 2: Inventory Data:

1. What is the name to identify Addis Ababa-Djibouti railway truck?

☐ Addis Ababa-Djibouti railway line ☐ Addis Ababa-Djibouti railway route

☐ Addis Ababa-Djibouti railway district ☐ Others (please specify) _____

2. How do you divide the railway truck?

☐ By stations ☐ By towns ☐ By regions ☐ Others (please specify) _____

3. Is there any bridge Identification Numbering System?

☐ Yes ☐ No If yes, please specify _____

4. Distance in km of Bridge location is measured from

☐ Starting of Station ☐ Specific Central Point

If specific Central point (please specify where) _____

Topic # 3: Inspection Data:

1. What different types of inspections are performed on railway bridges?

☐ Initial ☐ Visual (Regular) ☐ Detail (Major) ☐ Special (Emergency)

☐ Verification ☐ Fracture Critical ☐ Underwater Inspection ☐ Other (please specify)_____

2. What are the frequency / interval of railway bridge inspection in your Organization considering available budget and inspection personnel's?

Initial ☐ after 1 month ☐ after 2 months ☐ after 3 months ☐ Other (please specify) ____

Visual (Regular) ☐ Every month ☐ Every 6 months ☐ Every year ☐ Other (please specify) ____

Detail (Major) ☐ Every 2 years ☐ Every 3 years ☐ Every 5 years ☐ Other (please specify) ____

Special (Emergency) ☐ Immediately upon occurrence ☐ after a week

☐ after a month ☐ Other (please specify) _____

Verification ☐ after every Initial Inspection ☐ after every Visual (Regular) Inspection

☐ after every Detail (Major) Inspection ☐ Other (please specify) _____

Fracture Critical ☐ Every year ☐ Every 2 years ☐ Every 3 years ☐ Other (please specify) ____

Underwater ☐ Every 4 years ☐ Every 5 years ☐ Every 6 years ☐ Other (please specify) ____

Other (please specify) _____

3. Do you need to perform hands-on/close-up inspection? This is physically touching and sounding each and every elements of a bridge. This may require lane closure and use of an under-bridge inspection vehicle.

☐ No ☐ Yes

4. Do other bridge owners in our country follow the same inspection frequency as you do?

☐ No ☐ Yes. If yes, please specify ……

5. What requirements exist (if any) for special inspections (such as after a severe flood, earthquake, etc)?

_____

6. Are the inspection data integrated into a bridge management system for managing a maintenance, rehabilitation, and replacement program?

☐ No ☐ Yes.

7. Do you have a computerized Bridge Management System (BMS)?

☐ No ☐ Yes If yes, which one is it (please specify) _____

8. If yes, when did you start using a computerized BMS? _____

9. If no, what system are you using? How are you managing your bridges?

_____

10. What is your railway bridge inspection system status?

☐ Fully Developed ☐ Under Development ☐ Other (please specify)_____

11. What is your bridge inspection condition rating scale?

☐ 0(failed)-9(excellent) ☐ 0(Failed)-7(excellent) ☐ Bad, Fair, Good

☐ Failed, Very Poor, Poor, Fair, Very Fair, Good, Very Good, Excellent

☐ Other (please identify)_____

Topic # 4: Personnel Qualifications:

1. Which Personnel's are involved in railway bridge inspection?

☐ Bridge Coordinator ☐ Bridge Engineer ☐ Bridge Inspector

☐ Other (please specify)_____

2. Are a personnel's involved in Railway Bridge inspection formally certified?

☐ No ☐ Yes. ☐ Others (please specify)_____

3. If yes, who certified them?

☐ Ethiopian Railway Corporation ☐ Addis Ababa Light Rail Transit ☐ Others (please specify)_____

4. Are educational and physical qualifications required of inspectors?

☐ No ☐ Yes. ☐ If yes, what are the requirements (please specify)_____

5. If yes on Question No. 4 Who sets these requirements?

☐ Ethiopian Railway Corporation ☐ Addis Ababa Light Rail Transit ☐ Others (please specify)_____

6. How often are the inspectors trained?

☐ Semi-annually ☐ Annually ☐ Every 2 Years ☐ Every 5 Years ☐ Other (please specify)_____

7. Who trains them?

☐ Ethiopian Railway Corporation ☐ Addis Ababa Light Rail Transit ☐ Others (please specify)_____

Topic # 5: Process Control:

1. Is there any prepared standards, procedures, manuals, guidelines, etc. for railway bridge inventory and inspection in your Organization?

☐ No ☐ Yes. If yes, please specify_____

2. What role does your Organization play in the process of ensuring quality and safety of railway bridges inventory and inspection?

☐ Full role ☐ Some role ☐ No role Other, please specify_____

Topic # 6: Equipment:

1. What tool, Equipment and Facility are used for Inspection?

☐ Furnished office for Bridge Inspection Personnel's ☐ Computer, Printer and Other office tools

☐ High-rail cars (to ride both on highway and rail environments)

☐ Inspector's safety (protective) equipment's

☐ Different measuring Equipment's

☐ Other, please specify_____

2. Is any nondestructive evaluation, nondestructive testing, or other advanced testing equipment used during bridge inspection?

☐ No ☐ Yes If Yes, please specify type of equipment use_____

Topic # 7: Documentation:

1. Do standard inventory and inspection formats exist?

☐ No ☐ Yes.

2. If yes, for which types of inspection do the formats apply?

☐ Initial ☐ Visual (Regular) ☐ Detail (Major) ☐ Special (Emergency)

☐ Verification ☐ Fracture Critical ☐ Underwater Inspection ☐ Other (please specify)_____

3. What is the process of distribution, review and evaluation of inspection reports?

_____

_____

4. Who reviews the inspection reports?

☐ Bridge Inspection Coordinator ☐ Bridge Engineer ☐ Bridge Inspector

☐ Other, please specify_____

5. How long are inspection records kept?

☐ 1-5 Years ☐ 6-10 Years ☐ 11-15 Years ☐ 15-20 Years

☐ Life of the Bridge ☐ Forever ☐ Other, please specify_____

Topic # 8: General Comments

1. Are you satisfied with the bridge management of other Organizations in our country?

☐ Not Satisfied ☐ Partially Satisfied ☐ Fully Satisfied If fully satisfied; please specify the name of the Organizations _____

2. If not, how could (do you think) the bridge asset management system can be improved?

_____

_____

_____

After completing the survey, if there are issues pertaining to railway bridge inventory and inspection practices that you believe are important but, which are not addressed adequately by this questionnaire, please feel free to contact through Email: davobon100@gmail.com. This help for enriching the practice of safety and inspection in the Railway Bridge System.

Thank you for your time!!!

Appendix B

Questioner for staffs in Ethio-Djibouti Railway Line

Addis Ababa University

Addis Ababa Institute of Technology

School of Civil and Environmental Engineering

Railway Stream

Objectives of the Questionnaire

The primary objective of this questioner is to investigate and document Railway Bridge Inventory and Inspection practices on the Old Railway line along Addis Ababa-Diredawa-Djibouti. This questioner is an important input for the MSc. Thesis in the preparation of **Guideline for Inventory and Inspection of Railway Bridges.**

The main objective of the study is to prepare guideline for inventory and inspection of railway bridges to ensure that a bridge continues to perform its function under acceptable conditions of safety and with minimized cost of maintenance.

The research tries to address the following points:

- Inventory and Inspection formats
- Types and frequency of Inspection
- Procedures and Equipment's for Inventory and Inspection
- Safety Measures during Inventory and Inspection
- Suggested Personnel Requirements
- Reporting Inventory and Inspection Findings

Dear Respondents

Your response has considerable value in this study, Kindly respond to all questions. It is not required to write your name and the responses you give will be used only for this study and remain confidential. Email address in case you have question is davobon100@gmail.com.

Thank you for your cooperation!

General Instruction

- Put **'x'** in the boxes accompanied by various choices, to make your answer.
- You may tick more than one alternative answer wherever necessary.
- For open ended questions write your answer in the space provided.

General Information (as you was employee in the Old Railway Line along Addis Ababa-Djibouti):

Company Name: _____

Unit / Department: _____

Position/Title: _____

Highest Educational Level: ☐ Certificate ☐ Diploma ☐ BSc ☐ MSc ☐ PhD

Work Experience in year: ☐ < 2 years ☐ 3-5 years ☐ 6-10 years

☐ 11-15 years ☐ > 15 years

Topic # 1: Organizational Structure and Background:

1. Who was the owner of the old railway line along Addis Ababa-Dewele?

☐ Ethiopian Railway Company ☐ Government of Ethiopia and Djibouti

☐ Franco-Ethiopian Railway Company ☐ Other (please specify)_____

2. Who was responsible for inventory, inspection and maintenance of railway bridges in the old railway line along Addis Ababa-Dewele?

☐ Ethiopian Railway Company ☐ Combination of the Government of Ethiopia and Djibouti

☐ Franco-Ethiopian Railway Company ☐ Others (please specify) _____

3. Was there any Guideline related to inventory & inspection of bridges in the old railway line along Addis-Djibouti?

☐ No ☐ Yes. If yes, please specify the Guideline_____

4. Was there any Organizational regulation for railway bridge inventory, inspection and maintenance in the Organization?

☐ No ☐ Yes. If yes, please specify regulations_____

5. Was there any central database to manage railway bridges?

☐ No ☐ Yes

7. What was the total numbers of railway bridges registered?

Number of railway bridges_____ ☐ Unknown

8. How old were the bridges. What numbers of bridges were?

☐ <30 Years – No._____ ☐ <40 Years – No. _____ ☐ <50 Years – No._____

☐ <60 Years – No. _____ ☐ >60 Years – No._____ ☐ Unknown

9. What were the types of railway bridges?

A/ PRESTRESED CONCRETE

- ☐ PRECAST BOX GIRDER
- ☐ CAST IN PLACE BOX GIRDER
- ☐ PRECAST I - BEAM
- ☐ CAST IN PLACE I - BEAM
- ☐ PRECAST INTEGRAL BEAM AND SLAB
- ☐ CAST IN PLACE INTEGRAL BEAM AND SLAB
- ☐ PRECAST BOX UNITS
- ☐ CAST IN PLACE BOX UNITS
- ☐ PRECAST T - BEAMS
- ☐ CAST IN PLACE T - BEAMS
- ☐ PRECAST SLAB PANELS
- ☐ CAST IN PLACE SLAB PANELS
- ☐ RIGID FRAME BRIDGE
- ☐ EXTRADOSED BRIDGE

B/ REINFORCED CONCRETE

- ☐ BOX GIRDER
- ☐ DECK GIRDER
- ☐ ARCH
- ☐ PRECAST BOX UNITS
- ☐ CAST IN PLACE BOX UNITS
- ☐ SLAB

C/ STEEL CONCRETE COMPOSITE

- ☐ BOX GIRDER
- ☐ STEEL BEAMS & CONCRETE DECK

D/ STEEL

- ☐ I-BEAM
- ☐ STEEL ARCH
- ☐ TRUSS

If the types of bridges not included in the above list, please specify_____

_____

_____

Topic # 2: Inventory Data:

1. What was the name to identify the Old Addis Ababa-Djibouti railway truck?

☐ Addis Ababa-Djibouti railway line ☐ Addis Ababa-Djibouti railway route

☐ Addis Ababa-Djibouti railway corridor ☐ Others (please specify) _____

2. How did you divide the railway truck?

☐ By stations ☐ By towns ☐ By regions ☐ Others (please specify) _____

3. Was there any bridge Identification Numbering System?

☐ Yes ☐ No If yes, please specify _____

4. Distance in km of Bridge location was measured from

☐ Starting of Station ☐ Specific Central Point

If specific Central point (please specify where) _____

Topic # 3: Inspection Data:

1. What different types of inspections were performed on railway bridges?

☐ Initial ☐ Visual (Regular) ☐ Detail (Major) ☐ Special (Emergency)

☐ Verification ☐ Fracture Critical ☐ Underwater Inspection ☐ Other (please specify)_____

2. What were the frequency / interval of railway bridge inspection considering the following?

i. Available budget

Initial ☐ after 1 month ☐ after 2 months ☐ after 3 months ☐ Other (please specify) ____

Visual (Regular) ☐ Every month ☐ Every 6 months ☐ Every year ☐ Other (please specify) ____

Detail (Major) ☐ Every 2 years ☐ Every 3 years ☐ Every 5 years ☐ Other (please specify) ____

Special (Emergency) ☐ Immediately upon occurrence ☐ after a week

☐ after a month ☐ Other (please specify) _____

Verification ☐ after every Initial Inspection ☐ after every Visual (Regular) Inspection

☐ after every Detail (Major) Inspection ☐ Other (please specify) _____

Fracture Critical ☐ Every year ☐ Every 2 years ☐ Every 3 years ☐ Other (please specify) ____

Underwater ☐ Every 4 years ☐ Every 5 years ☐ Every 6 years ☐ Other (please specify) ____

Other (please specify) _____

ii. Inspection personnel's

Initial ☐ after 1 month ☐ after 2 months ☐ after 3 months ☐ Other (please specify) ____

Visual (Regular) ☐ Every month ☐ Every 6 months ☐ Every year ☐ Other (please specify) ____

Detail (Major) ☐ Every 2 years ☐ Every 3 years ☐ Every 5 years ☐ Other (please specify) ____

Special (Emergency) ☐ Immediately upon occurrence ☐ after a week

☐ after a month ☐ Other (please specify) _____

Verification ☐ after every Initial Inspection ☐ after every Visual (Regular) Inspection

☐ after every Detail (Major) Inspection ☐ Other (please specify) _____

Fracture Critical ☐ Every year ☐ Every 2 years ☐ Every 3 years ☐ Other (please specify) ____

Underwater ☐ Every 4 years ☐ Every 5 years ☐ Every 6 years ☐ Other (please specify) ____

Other (please specify) _____

3. Did you perform hands-on/close-up inspection? This is physically touching and sounding each and every elements of a bridge. This may require lane closure and use of an under-bridge inspection vehicle.

☐ No ☐ Yes

4. Did other bridge owners in our country follow the same inspection frequency as you did?

☐ No ☐ Yes. If yes, please specify ……

5. What requirements existed (if any) for special inspections (such as after a severe flood, earthquake, etc)?

_____

6. Were the inspection data integrated into bridge management system software for managing a maintenance, rehabilitation, and replacement program?

☐ No ☐ Yes.

7. Did you make use of a computerized Bridge Management System (BMS)?

☐ No ☐ Yes If yes, which one is it (please specify) _____

8. If yes, when did you start using a computerized BMS? _____

9. If no, what system did you using? How did you managing your bridges?

_____

_____

10. What was your railway bridge inspection system status?

☐ Fully Developed ☐ Partially Developed ☐ Other (please specify)_____

11. What was your bridge inspection condition rating scale?

☐ 0(failed)-9(excellent) ☐ 0(Failed)-7(excellent) ☐ Bad, Fair, Good

☐ Failed, Very Poor, Poor, Fair, Very Fair, Good, Very Good, Excellent

☐ Other (please identify) _____

12. Please fill the following table related with famous Bridge Failures during the operation of the old railway line.

It No.	Name of the River	Name of the Bridge	Location of the Bridge	Year of Bridge Failure	Reason for Bridge Failure	What was the Consequence of bridge failure
1						
2						
3						
4						

13. What was the main reason for termination of operation of the old Ethio-Djibouti Railway Line?

☐ Lack of maintenance and frequent accident ☐ Lack of budget

☐ Lack of Professional Personnel to administer the railway line ☐ Others (please specify)_____

_____

_____

Topic # 4: Personnel Qualifications:

1. Which Personnel's were involved in railway bridge inspection?

☐ Bridge Coordinator ☐ Bridge Engineer ☐ Bridge Inspector

☐ Assistant Bridge Inspector ☐ Other (please specify) _____

2. Were a personnel's involved in Railway Bridge inspection formally certified?

☐ No ☐ Yes. ☐ Others (please specify)_____

3. If yes, who certified them?

☐ Ethiopian Railway Company ☐ Transport Ministry

☐ Franco-Ethiopian Railway Company ☐ Others (please specify)_____

4. Were educational and physical qualifications required of inspectors?

☐ No ☐ Yes. ☐ If yes, what are the requirements (please specify)_____

5. If yes on Question No. 4, who was setting these requirements?

☐ Ethiopian Railway Corporation ☐ Franco-Ethiopian Railway Company ☐ Others (please specify)_____

6. How often were the inspectors trained?

☐ Semi-annually ☐ Annually ☐ Every 2 Years ☐ Every 5 Years ☐ Other (please specify)_____

7. Who trained them?

☐ Ethiopian Railway Corporation ☐ Franco-Ethiopian Railway Company ☐ Others (please specify)_____

Topic # 5: Process Control:

1. Was there any prepared standards, procedures, manuals, guidelines, etc. for railway bridge inventory and inspection?

   ☐ No ☐ Yes. If yes, please specify_____

2. What role did your Organization played in the process of ensuring quality and safety of railway bridges inventory and inspection?

   ☐ Full role ☐ Some role ☐ No role Other, please specify_____

Topic # 6: Equipment:

1. What tool, Equipment and Facility were used for Inspection?

   ☐ Furnished office for Bridge Inspection Personnel's ☐ Computer, Printer and Other office tools

   ☐ High-rail cars (to ride both on highway and rail environments)

   ☐ Inspector's safety (protective) equipment's ☐ Lifting Cranes

   ☐ Different measuring Equipment's

   ☐ Other, please specify_____

2. What tool, Equipment and Facility were used for Train Accidents and Derailments?

   ☐ An emergency train, loaded with lifting gear ☐ Camping equipment

   ☐ Food and water for Emergency teams ☐ Other, please specify _____

3. Was any nondestructive evaluation, nondestructive testing, or other advanced testing equipment used during bridge inspection?

   ☐ No ☐ Yes If Yes, please specify type of equipment use_____

Topic # 7: Documentation:

1. Did standard inventory and inspection formats exist?

☐ No ☐ Yes.

2. If yes, for which types of inspection did the formats apply?

☐ Initial ☐ Visual (Regular) ☐ Detail (Major) ☐ Special (Emergency)

☐ Verification ☐ Fracture Critical ☐ Underwater Inspection ☐ Other (please specify)_____

3. What was the process of distribution, review and evaluation of inspection reports?

_____

_____

4. Who reviewed the inspection reports?

☐ Bridge Inspection Coordinator ☐ Bridge Engineer ☐ Bridge Inspector

☐ Other, please specify_____

5. How long were inspection records kept?

☐ 1-5 Years ☐ 6-10 Years ☐ 11-15 Years ☐ 15-20 Years

☐ Life of the Bridge ☐ Forever ☐ Other, please specify_____

Topic # 8: General Comments

1. Were you satisfied with the bridge management of other Organizations in our country?

☐ Not Satisfied ☐ Partially Satisfied ☐ Fully Satisfied If fully satisfied; please specify the name of the Organizations _____

2. If not, how could (do you think) the bridge asset management system can be improved?

_____

_____

_____

After completing the survey, if there are issues pertaining to railway bridge inventory and inspection practices that you believe are important but, which are not addressed adequately by this questionnaire, please feel free to contact through Email: davobon100@gmail.com. This help for enriching the practice of safety and inspection in the Railway Bridge System.

Thank you for your time!!!

Appendix C

Questioner for Bridge Professionals

Addis Ababa University

Addis Ababa Institute of Technology

School of Civil and Environmental Engineering

Railway Stream

Objectives of the Questionnaire

This Questionnaire is prepared to conduct a research for the partial fulfillment of the requirement of the degree of Master of Science in Railway Engineering entitled Preparation of Inventory and Inspection Guideline for Railway Bridge in Ethiopia.

Dear Respondents

Your response has considerable value in this study, Kindly respond to all questions. It is not required to write your name and the responses you give will be used only for this study and remain confidential. Email address in case you have question is davobon100@gmail.com.

Thank you for your cooperation!

General Instruction

- Put **'x'** in the boxes accompanied by various choices, to make your answer.
- You may tick more than one alternative answer wherever necessary.
- For open ended questions write your answer in the space provided.

Respondents Profile:

1. Gender ☐ Male ☐ Female

2. Age ☐ 20-29 Years ☐ 30-39 Years ☐ 40-49 years ☐ > 50 years

3. Educational status ☐ Certificate ☐ Diploma ☐ BSc ☐ MSc ☐ PhD

4. Company Name: _____

5. Position/Title: _____

6. Work Experience in year: ☐ < 2 years ☐ 3-5 years ☐ 6-10 years
☐ 11-15 years ☐ > 15 years

7. Main areas that occupy most of your time as a structural engineer:

☐ Design ☐ Supervision ☐ Construction ☐ Maintenance

☐ Bridge Management Consulting Service

☐ Bridge Asset Management / Administration

Topic # 1: Inventory Data:

1. What are the types of railway bridges encountered in your practice in Ethiopia?

A/ PRESTRESED CONCRETE

- ☐ PRECAST BOX GIRDER
- ☐ CAST IN PLACE BOX GIRDER
- ☐ PRECAST I - BEAM
- ☐ CAST IN PLACE I - BEAM
- ☐ PRECAST INTEGRAL BEAM AND SLAB
- ☐ CAST IN PLACE INTEGRAL BEAM AND SLAB
- ☐ PRECAST BOX UNITS
- ☐ CAST IN PLACE BOX UNITS
- ☐ PRECAST T - BEAMS
- ☐ CAST IN PLACE T - BEAMS
- ☐ PRECAST SLAB PANELS
- ☐ CAST IN PLACE SLAB PANELS
- ☐ RIGID FRAME BRIDGE
- ☐ EXTRADOSED BRIDGE

B/ REINFORCED CONCRETE

- ☐ BOX GIRDER
- ☐ DECK GIRDER
- ☐ ARCH
- ☐ PRECAST BOX UNITS
- ☐ CAST IN PLACE BOX UNITS
- ☐ SLAB

C/ STEEL CONCRETE COMPOSITE

- ☐ BOX GIRDER
- ☐ STEEL BEAMS & CONCRETE DECK

D/ STEEL

- ☐ I-BEAM
- ☐ STEEL ARCH
- ☐ TRUSS

If the type of bridge is not included in the above list, please specify_____

_____

_____

2. What would be the span length appropriate to be bridge in bridge asset management in your opinion?

☐ ≥4.0m ☐ ≥4.5m ☐ ≥5.0m ☐ ≥5.5m ☐ ≥6.0m ☐ >6.0m

Topic # 2: Inspection Data:

1. Factors attribute to the deteriorate condition of bridges over time?

☐ live load ☐ flood ☐ wind ☐ earthquake ☐ collision,

☐ environmental factors ☐ factors ☐ fatigue

2. Types of inspections performed on highway bridges:

☐ Initial ☐ Visual (Regular) ☐ Detail (Major) ☐ Special (Emergency)

☐ Verification ☐ Fracture Critical ☐ Underwater Inspection

☐ Other (please specify) _____

3. What are the frequency / interval of railway bridge inspection in years considering time since last inspection, for?

i. Structure type and measurement

Initial_____ Visual (Regular) _____ Detail (Major) _____ Special (Emergency)____

Verification_____ Fracture Critical_____ Underwater_____ Other (please specify)_____

ii. Structure condition

Initial_____ Visual (Regular) _____ Detail (Major) _____ Special (Emergency)____

Verification_____ Fracture Critical_____ Underwater_____ Other (please specify)___

iii. Structure age

Initial_____ Visual (Regular) _____ Detail (Major) _____ Special (Emergency)____

Verification_____ Fracture Critical_____ Underwater_____ Other (please specify)___

iv. Following natural disasters (floods, bushfires and earthquakes)

Initial_____ Visual (Regular) _____ Detail (Major) _____ Special (Emergency)____

Verification_____ Fracture Critical_____ Underwater_____ Other (please specify)___

4. Types of Highway Bridge Inspection Practice in Ethiopia

☐ Visual Inspection ☐ In Situ Testing ☐ Laboratory Investigation

☐ Other (please specify)_____

5. What requirements exist (if any) for special inspections (such as after a severe flood, earthquake, etc)?

_____
_____
_____

6. Briefly describe the systematic procedures of inspection use at a typical sketch of a bridge.

_____
_____
_____
_____
_____

7. Possible recommendation of the inspector team after inspecting the existing bridges with:

i. Scour at pier and /or abutment

☐ Replacement ☐ Rehabilitation ☐ Regular Inspection ☐ Preventive Maintenance

☐ Corrective Maintenance ☐ Other, please specify _____

ii. Overtopping

☐ Replacement ☐ Rehabilitation ☐ Regular Inspection ☐ Preventive Maintenance

☐ Corrective Maintenance ☐ Other, please specify _____

iii. Road and post crushing

☐ Replacement ☐ Rehabilitation ☐ Regular Inspection ☐ Preventive Maintenance

☐ Corrective Maintenance ☐ Other, please specify _____

iv. Pot holes with Rebar exposure in Deck

☐ Replacement ☐ Rehabilitation ☐ Regular Inspection ☐ Preventive Maintenance

☐ Corrective Maintenance ☐ Other, please specify _____

v. Water Leakage on Deck

☐ Replacement ☐ Rehabilitation ☐ Regular Inspection ☐ Preventive Maintenance

☐ Corrective Maintenance ☐ Other, please specify _____

vi. Shear Crack on Girder _____mm wide, _____mm long

☐ Replacement ☐ Rehabilitation ☐ Regular Inspection ☐ Preventive Maintenance

☐ Corrective Maintenance ☐ Other, please specify _____

vii. Flexural Crack _____ mm wide, _____mm long

☐ Replacement ☐ Rehabilitation ☐ Regular Inspection ☐ Preventive Maintenance

☐ Corrective Maintenance ☐ Other, please specify _____

viii. Foundation settlement

☐ Replacement ☐ Rehabilitation ☐ Regular Inspection ☐ Preventive Maintenance

☐ Corrective Maintenance ☐ Other, please specify _____

8. Which of the following rating scale express Bridge Inspection Condition?

☐ Very Good, Good, Fair, Poor, Very Poor ☐ 0(Failed)-7(excellent) ☐ Bad, Fair, Good

☐ Failed, Very Poor, Poor, Fair, Very Fair, Good, Very Good, Excellent

☐ Other (please identify)_____

9. Who should carry out bridge asset inspection?

☐ Bridge's Owner own forces ☐ Consultants ☐ Owners and Consultants

☐ Other (please specify) _____

Topic # 3: Bridge Defects / Damages

1. Which of the following bridge defects / damages are common to your practice? Mark in the table below:

RC, Pre stress, Steel and Composite Bridge Defects					
	Cracking		Water Leakage		Noise
	Peel Off		Efflorescence		Excessive Vibration
	Rebar Exposure		Foundation, Abutment & Wing wall Settlement, Inclination		Bearing Main Damage
	Steel Corrosion		Scour		Bearing Parts missing
	Steel Deformation		Siltation		Bearing Anchor Damage
	Steel Paint Peel off		Over flooding		Bearing Bed Damage
	Bolt Missing		Stone deterioration		Bearing Unusual movement
	Honeycomb		Bulging		Bearing Dislocation
	Spalling, Delamination		Embankment Depression		Pipe Damage
	Material Deterioration		Embankment Erosion		Pipe Blocked
	Void		Missing		Pipe Inlet Damage

If there are other bridge defects which are not included in the table above, please specify:_____
_____
_____

2. How do you rate **Extent of bridge defect / damage**?

☐ No Significant defect, Slight, Moderate, Wide, Extensive

☐ No Significant defect, Moderate, Wide, Extensive

☐ No defect, Moderate, Extensive

☐ Other, Please specify_____

3. What are the percentages of the **extent of bridge defects** compared with the total bridge dimensions?

No Significant Defect ☐ 0% ☐ 0-5% ☐ 0-7.5% ☐ Other, Please specify_____

Slight Defect ☐ 0-5% ☐ 5-7.5% ☐ 5-10% ☐ Other, Please specify_____

Moderate Defect ☐ 5-10% ☐ 10-15% ☐ 15-20% ☐ Other, Please specify_____

Wide Defect ☐ 15-20% ☐ 20-30% ☐ 30-50% ☐ Other, Please specify_____

Extensive Defects ☐ 30-50% ☐ 40-60% ☐ >50% ☐ Other, Please specify_____

4. How do you rate **Degree/ Severity** of defect/Damage?

☐ Failed, Sever, Moderate, Minor, New

☐ Severe, Warning, Minor, None

☐ Rank A, Rank B, Rank C, where of Rank A_____ Rank B_____ Rank C_____

☐ Other, Please specify_____

5. How do you rate **Relevancy** of defect / damage?

☐ No significant importance, Minor, Moderate, Major, Critical

☐ Minor, Moderate, Major, Critical

☐ Minor, Major, Critical

☐ Other, Please specify_____

6. How do you rate Relevancy of **defect / damage** out of 100% of whole Bridge?

No significant importance	☐ 1%	☐ 5%	☐ 10%	☐ Other, Please specify_____
Minor	☐ 5%	☐ 10%	☐ 15%	☐ Other, Please specify_____
Moderate	☐ 10%	☐ 15%	☐ 20%	☐ Other, Please specify_____
Major	☐ 15%	☐ 20%	☐ 30%	☐ Other, Please specify_____
Critical	☐30%	☐ 40%	☐ 60	☐ Other, Please specify_____

7. How much is the %age **Importance** of railway bridge elements out of 100% of whole Bridge.

Bridge Superstructure	☐30%	☐ 40%	☐ 50%	☐ Other, Please specify_____
Bridge Substructure	☐ 30%	☐ 40%	☐ 50%	☐ Other, Please specify_____
Bridge Ancillary	☐ 5%	☐ 10%	☐ 15%	☐ Other, Please specify_____
Railway Truck Structure over the bridge	☐ 10%	☐ 15%	☐20%	☐ Other, Please specify_____

8. How much is the %age Importance of railway bridge **RC Superstructure** elements listed below out of 100% of whole RC Superstructure elements.

Deck Slab	☐ 20%	☐ 30%	☐ 40%	☐ Other, Please specify_____
Concrete Girder	☐ 40%	☐ 60%	☐ 70%	☐ Other, Please specify_____

9. How much is the %age Importance of railway bridge **Steel Superstructure elements** listed below out of 100% of whole Steel Superstructure elements.

Steel Deck	☐ 20%	☐ 30%	☐ 40%	☐ Other, Please specify_____
Steel Girder	☐ 40%	☐ 60%	☐ 70%	☐ Other, Please specify_____

10. How much is the %age Importance of railway bridge **Substructure elements** listed below out of 100% of whole Substructure elements.

Pier & Foundation	☐30%	☐ 40%	☐ 50%	☐ Other, Please specify_____
Abutment & Wing wall	☐30%	☐ 40%	☐ 50%	☐ Other, Please specify_____
Embankment	☐5%	☐ 10%	☐ 20%	☐ Other, Please specify_____
Rip Rap	☐5%	☐ 10%	☐ 15%	☐ Other, Please specify_____

11. How much is the %age Importance of Railway Bridge **Ancillaries Elements** listed below out of 100% of whole Ancillaries Elements.

Bearing	☐40%	☐ 50%	☐ 60%	☐ Other, Please specify_____
Expansion Joint	☐10%	☐ 20%	☐ 30%	☐ Other, Please specify_____
Deck Drains	☐10%	☐ 15%	☐ 20%	☐ Other, Please specify_____
Kerb, Railing & Post	☐10%	☐ 15%	☐ 20%	☐ Other, Please specify_____

12. How much is the %age Importance of **Railway Track Structure Elements** listed below over the bridge out of 100% of whole Railway Track Structure.

Rail	☐20%	☐ 30%	☐ 40%	☐ Other, Please specify_____
Rail Fasteners	☐5%	☐ 10%	☐ 20%	☐ Other, Please specify_____
Sleeper	☐5%	☐ 10%	☐ 20%	☐ Other, Please specify_____
Ballast	☐0%	☐ 10%	☐ 20%	☐ Other, Please specify_____
Ballast Retainers	☐0%	☐ 10%	☐ 15%	☐ Other, Please specify_____

Note that 0% refers for case not applicable.

13. How much is the %age Importance of railway bridge **Deck Slab Defects** listed below out of 100% of whole Deck Slab Defects.

Cracking	☐10%	☐ 20%	☐ 30%	☐ Other, Please specify_____
Peel off	☐5%	☐ 10%	☐ 15%	☐ Other, Please specify_____
Rebar Exposure	☐10%	☐ 20%	☐ 30%	☐ Other, Please specify_____
Honeycomb	☐5%	☐ 10%	☐ 15%	☐ Other, Please specify_____
Void	☐5%	☐ 10%	☐ 15%	☐ Other, Please specify_____
Water Leakage	☐5%	☐ 10%	☐ 20%	☐ Other, Please specify_____

14. How much is the %age Importance of railway bridge **Concrete Girder Defects** listed below out of 100% of whole Concrete Girder Defects.

Cracking	☐10%	☐ 20%	☐ 30%	☐ Other, Please specify_____
Peel off	☐5%	☐ 10%	☐ 15%	☐ Other, Please specify_____
Rebar Exposure	☐10%	☐ 20%	☐ 30%	☐ Other, Please specify_____
Honeycomb	☐5%	☐ 10%	☐ 15%	☐ Other, Please specify_____
Void	☐5%	☐ 10%	☐ 15%	☐ Other, Please specify_____
Water Leakage	☐5%	☐ 10%	☐ 20%	☐ Other, Please specify_____

15. How much is the %age Importance of railway bridge **Steel Girder Defects** listed below out of 100% of whole Steel Girder Defects.

Deformation	☐10%	☐ 20%	☐ 30%	☐ Other, Please specify_____
Cracking	☐10%	☐ 15%	☐ 20%	☐ Other, Please specify_____
Corrosion	☐10%	☐ 15%	☐ 20%	☐ Other, Please specify_____
Wearing	☐5%	☐ 10%	☐ 15%	☐ Other, Please specify_____
Bolt Missing	☐5%	☐ 10%	☐ 15%	☐ Other, Please specify_____
Paint Peel off	☐5%	☐ 10%	☐ 15%	☐ Other, Please specify_____

16. How much is the %age Importance of railway bridge **Pier & Foundation Defects** listed below out of 100% of whole Pier & Foundation Defects.

Cracking	☐10%	☐ 20%	☐ 30%	☐ Other, Please specify_____
Peel off / Stone Deterioration	☐5%	☐ 10%	☐ 15%	☐ Other, Please specify_____
Rebar Exposure	☐10%	☐ 15%	☐ 20%	☐ Other, Please specify_____
Honeycomb	☐5%	☐ 10%	☐ 20%	☐ Other, Please specify_____
Void	☐5%	☐ 10%	☐ 20%	☐ Other, Please specify_____
Water Leakage	☐5%	☐ 10%	☐ 20%	☐ Other, Please specify_____
Displacement / Bulging	☐10%	☐ 20%	☐ 30%	☐ Other, Please specify_____
Scour	☐10%	☐ 20%	☐ 30%	☐ Other, Please specify_____

17. How much is the %age Importance of Railway Bridge **Abutment & Wing wall Defects** listed below out of 100% of whole Abutment & Wing wall Defects.

Cracking	☐10%	☐ 20%	☐ 30%	☐ Other, Please specify_____
Peel off / Stone Deterioration	☐5%	☐ 10%	☐ 15%	☐ Other, Please specify_____
Rebar Exposure	☐10%	☐ 15%	☐ 20%	☐ Other, Please specify_____
Honeycomb	☐5%	☐ 10%	☐ 20%	☐ Other, Please specify_____
Void	☐5%	☐ 10%	☐ 20%	☐ Other, Please specify_____
Water Leakage	☐5%	☐ 10%	☐ 20%	☐ Other, Please specify_____
Displacement / Bulging	☐10%	☐ 20%	☐ 30%	☐ Other, Please specify_____
Scour	☐10%	☐ 20%	☐ 30%	☐ Other, Please specify_____

18. How much is the %age Importance of railway bridge **Embankment Defects** listed below out of 100% of whole Embankment Defects.

Depression	☐30%	☐ 40%	☐ 70%	☐ Other, Please specify_____
Erosion	☐30%	☐ 40%	☐ 70%	☐ Other, Please specify_____

19. How much is the %age Importance of railway bridge **Rip Rap Defects** listed below out of 100% of whole Rip Rap Defects.

Missing	☐30%	☐ 40%	☐ 50%	☐ Other, Please specify_____
Erosion	☐20%	☐ 30%	☐ 40%	☐ Other, Please specify_____
Displacement	☐20%	☐ 30%	☐ 40%	☐ Other, Please specify_____

20. How much is the %age Importance of railway bridge **Bearing Defects** listed below out of 100% of whole Bearing Defects.

Main Damage	☐20%	☐ 30%	☐ 40%	☐ Other, Please specify_____
Parts Missing	☐5%	☐ 10%	☐ 15%	☐ Other, Please specify_____
Anchor Damage	☐5%	☐ 10%	☐ 20%	☐ Other, Please specify_____
Bed Damage	☐5%	☐ 10%	☐ 20%	☐ Other, Please specify_____
Unusual Movement	☐10%	☐ 20%	☐ 30%	☐ Other, Please specify_____

21. How much is the %age Importance of railway bridge **Expansion Joint Defects** listed below out of 100% of whole Expansion Joint Defects.

Deformation	☐5%	☐ 10%	☐ 20%	☐ Other, Please specify_____
Water Leakage	☐5%	☐ 10%	☐ 20%	☐ Other, Please specify_____
Peel off	☐5%	☐ 10%	☐ 20%	☐ Other, Please specify_____
Missing	☐5%	☐ 10%	☐ 20%	☐ Other, Please specify_____
Noise	☐5%	☐ 10%	☐ 20%	☐ Other, Please specify_____

22. How much is the %age Importance of railway bridge **Kerb & Railing Defects** listed below out of 100% of whole Kerb & Railing Defects.

Cracking	☐5%	☐ 10%	☐ 20%	☐ Other, Please specify_____
Peel off	☐5%	☐ 10%	☐ 20%	☐ Other, Please specify_____
Rebar Exposure	☐5%	☐ 10%	☐ 20%	☐ Other, Please specify_____
Deformation	☐5%	☐ 10%	☐ 20%	☐ Other, Please specify_____
Corrosion	☐5%	☐ 10%	☐ 20%	☐ Other, Please specify_____
Missing	☐5%	☐ 10%	☐ 20%	☐ Other, Please specify_____

23. How much is the %age Importance of railway bridge **Drainage Defects** listed below out of 100% of whole Drainage Defects.

Pipe Damage	☐10%	☐ 20%	☐ 40%	☐ Other, Please specify_____
Blocked	☐10%	☐ 20%	☐ 40%	☐ Other, Please specify_____
Inlet Damage	☐10%	☐ 20%	☐ 30%	☐ Other, Please specify_____

24. How much is the %age Importance of **Railway Track Structure Element Defects over the bridge** out of 100% of whole Railway Track Structure Elements**.**

Defects on Rail	☐10%	☐ 20%	☐ 30%	☐ Other, Please specify_____
Defects on Rail Fasteners	☐5%	☐ 10%	☐ 15%	☐ Other, Please specify_____
Defects on Sleeper	☐10%	☐ 15%	☐ 20%	☐ Other, Please specify_____
Defects on Ballast	☐10%	☐ 15%	☐ 20%	☐ Other, Please specify_____
Defects on Ballast Retainers	☐5%	☐ 7.5%	☐ 10%	☐ Other, Please specify_____

Topic # 4: Measuring Railway Bridge Defects

Note:-

- Tick in the boxes in the table below, to make your answer.
- Only one alternative is possible for each row of the table.
- If you tick in alternative "Other" please specify in the space provided.

It No.	Types of Railway Bridge Defects	Measuring Unit	Bridge Defect Severity	Defect Size									
1	Cracking	mm	**New Condition**	0.00	0.25	0.50	0.75	Other, please specify					
			Minor Defect	1.00	1.50	2.00	2.50	Other, please specify					
			Moderate Defect	3.00	3.50	4.00	4.50	Other, please specify					
			Sever Defect	5.00	5.50	6.00	6.50	Other, please specify					
			Failed	7.00	7.50	8.00	> 8.00	Other, please specify					
2	Peel Off	cm^2	**New Condition** (Very small peel off)	0.00	25.00	50.00	100.00	Other, please specify					
			Minor Defect (Small range of peel off due to external forces)	150.00	200.00	300.00	400.00	Other, please specify					
			Moderate Defect (Wide range of peel off due to rebar corrosion)	500.00	630.00	760.00	900.00	Other, please specify					
			Sever Defect (Serious peel off)	1,000.00	1,150.00	1,300.00	1,450.00	Other, please specify					
			Failed (Serious peel off which couses concrete falling down)	1,600.00	1,800.00	2,000.00	>2200.00	Other, please specify					
3	Rebar Exposure	cm^2	**New Condition**	0.00	100.00	200.00	300.00	Other, please specify					
			Minor Defect (Partial rebar exposure without corrosion)	400.00	530.00	660.00	800.00	Other, please specify					
			Moderate Defect (Partial rebar exposure with corrosion)	1,000.00	1,160.00	1,320.00	1,500.00	Other, please specify					
			Sever Defect (Serious and wide range of rebar exposure together with corrosion)	1,700.00	2,130.00	2,560.00	3,000.00	Other, please specify					
			Failed (Serious and wide range of rebar exposure together with corrosion which causes a reduction in loading capacity)	3,500.00	4,000.00	4,500.00	> 5000.00	Other, please specify					
4	Honeycomb	cm^2	**New Condition**	0.00	100.00	200.00	300.00	Other, please specify					
			Minor Defect (Which affects the durability)	400.00	530.00	660.00	800.00	Other, please specify					
			Moderate Defect (With Seriously corroded rebar)	1,000.00	1,160.00	1,320.00	1,500.00	Other, please specify					
			Sever Defect (With seriously corroded rebar, which causes a reduction in loading capacity)	1,700.00	2,130.00	2,560.00	3,000.00	Other, please specify					
			Failed (with very serious damage to the rebar, which causes the closure of the bridge)	3,500.00	4,000.00	4,500.00	> 5000.00	Other, please specify					
5	Void	cm^3	**New Condition**	0.00	33.00	66.00	100.00	Other, please specify					
			Minor Defect (Wide range of voids without water leakage)	230.00	360.00	490.00	600.00	Other, please specify					
			Moderate Defect (With serious water leakage, multiple voids volume of)	700.00	800.00	900.00	1,000.00	Other, please specify					
			Sever Defect (With serious and continuous water leakage, multiple voids volume of)	1,150.00	1,300.00	1,450.00	1,600.00	Other, please specify					
			Failed (With serious and continuous water leakage, multiple voids volume, which causes the closure of the bridge)	1,750.00	1,900.00	2,050.00	>2200.00	Other, please specify					
6	WaterLeakage	cm^2	**New Condition**	0.00	100.00	200.00	300.00	Other, please specify					
			Minor Defect (Localized or partial water leakage)	400.00	530.00	660.00	800.00	Other, please specify					
			Moderate Defect (Serious and wide range of water leakage through cracks or voids)	1,000.00	1,160.00	1,320.00	1,500.00	Other, please specify					
			Sever Defect (Serious and wide range of water leakage through cracks or voids which may progress)	1,700.00	2,130.00	2,560.00	3,000.00	Other, please specify					
			Failed (Serious and wide range of water leakage through cracks or voids which may progress and cause a reduction in loading capacity, together with leaching free lime or salt)	3,500.00	4,000.00	4,500.00	> 5000.00	Other, please specify					
7	End Block Damage (Prestressed Concrete Bridge)	mm	**New Condition**	0.00	0.25	0.50	0.75	Other, please specify					
			Minor Defect (Spot cracking)	1.00	1.50	2.00	2.50	Other, please specify					
			Moderate Defect (Partial cracking)	3.00	3.50	4.00	4.50	Other, please specify					
			Sever Defect (Outstanding damage, such as cracking on the main end block member, which affects the loading capacity)	5.00	5.50	6.00	6.50	Other, please specify					
			Failed	7.00	7.50	8.00	> 8.00	Other, please specify					
8	End Bearing Plate Damage (Prestressed Concrete Bridge)	cm^2	**New Condition**	0.00	100.00	200.00	300.00	Other, please specify					
			Minor Defect (Partial corrosion)	400.00	530.00	660.00	800.00	Other, please specify					
			Moderate Defect (End bearing plates are partially broken or corroded)	1,000.00	1,160.00	1,320.00	1,500.00	Other, please specify					
			Sever Defect (End bearing plates are broken in wide range which loses anchoring functions)	1,700.00	2,130.00	2,560.00	3,000.00	Other, please specify					
			Failed	3,500.00	4,000.00	4,500.00	> 5000.00	Other, please specify					

It No.	Types of Railway Bridge Defects	Measuring Unit	Bridge Defect Severity	Defect Size											
9	Pipe-Damage	Out of 100% of whole Drainage Pipes	**New Condition**		0%		2.50%		5%		7.50%		Other, please specify		
			Minor Defect (Locally damaged pipe, which causes negative effects to other bridge elements)		7.50%		10%		15%		20%		Other, please specify		
			Moderate Defect (reduces durability of other bridge elements (results in corrosion of metal components or rebar))		20%		25%		30%		35%		Other, please specify		
			Sever Defect (causes heavy problem to others by falling down)		35%		40%		45%		50%		Other, please specify		
			Failed		50%		55%		60%		>60%		Other, please specify		
10	Blocked	Out of 100% of whole Drainage Pipes	**New Condition**		0%		2.50%		5%		7.50%		Other, please specify		
			Minor Defect (Slight blockage)		7.50%		10%		15%		20%		Other, please specify		
			Moderate Defect (Causes standing water during rainfall, effecting on traffic)		20%		25%		30%		35%		Other, please specify		
			Sever Defect (causes serious hindrance in safety to daily traffic and traffic interruption during and after rain)		35%		40%		45%		50%		Other, please specify		
			Failed		50%		55%		60%		>60%		Other, please specify		
11	Inlet-Damage	Out of 100% of whole Drainage Pipes	**New Condition**		0%		2.50%		5%		7.50%		Other, please specify		
			Minor Defect (Slight damage)		7.50%		10%		15%		20%		Other, please specify		
			Moderate Defect (Reduces drainage function)		20%		25%		30%		35%		Other, please specify		
			Sever Defect (Causes a hindrance to traffic)		35%		40%		45%		50%		Other, please specify		
			Failed		50%		55%		60%		>60%		Other, please specify		
12	Displacement	mm	**New Condition**		0.00		3.30		6.60		10.00		Other, please specify		
			Minor Defect (Causes no negative effect)		13.75		17.25		21.00		25.00		Other, please specify		
			Moderate Defect (Causes reduces stability)		31.25		37.50		43.75		50.00		Other, please specify		
			Sever Defect (which may progress and cause reduce stability)		50.00		56.25		62.50		75.00		Other, please specify		
			Failed		80.00		90.00		100.00		> 100.00		Other, please specify		
13	Scour	m	**New Condition**		0.00		0.10		0.15		0.25		Other, please specify		
			Minor Defect (Minor scouring to element in river is suspected)		0.15		0.25		0.50		0.75		Other, please specify		
			Moderate Defect (Foundation is exposed up to the top of footing or caisson, which may progress and cause a reduction in stability)		0.50		0.75		1.00		1.25		Other, please specify		
			Sever Defect (Foundation is exposed in depth from the top of footing, caisson or design datum level for pile bent, which may progress and cause a serious reduction in stability of foundation)		1.00		1.25		1.50		1.75		Other, please specify		
			Failed		1.50		1.75		2.00		> 2.00		Other, please specify		
14	Depression	mm	**New Condition**		0.00		3.30		6.60		10.00		Other, please specify		
			Minor Defect (Slight depression)		13.75		17.25		21.00		25.00		Other, please specify		
			Moderate Defect (Serious depression, which may progress and cause a hazard to traffic)		31.25		37.50		43.75		50.00		Other, please specify		
			Sever Defect (Outstanding crack or depression, which may progress and cause a hazard to traffic)		50.00		56.25		62.50		75.00		Other, please specify		
			Failed		80.00		90.00		100.00		> 100.00		Other, please specify		
15	Main - Damage for Bearing	Out of 100% of whole Bearing	**New Condition**		0%		2.50%		5%		7.50%		Other, please specify		
			Minor Defect (Spot cracking, corrosion or swelling of main element)		7.50%		10%		15%		20%		Other, please specify		
			Moderate Defect (Partial cracking, corrosion or swelling of main element)		20%		25%		30%		35%		Other, please specify		
			Sever Defect (Outstanding damage, such as cracking on the main bearing member, which affects the loading capacity on metal bearing)		35%		40%		45%		50%		Other, please specify		
			Failed		50%		55%		60%		>60%		Other, please specify		
16	Parts Missing for Bearing	Out of 100% of whole Bearing	**New Condition**		0%		2.50%		5%		7.50%		Other, please specify		
			Minor Defect (Slight damage)		7.50%		10%		15%		20%		Other, please specify		
			Moderate Defect (Partial cracking, incline or swelling on the secondary elements)		20%		25%		30%		35%		Other, please specify		
			Sever Defect (Secondary elements, such as stopper, anti- lift devices, are broken which reduces bearing function on metal bearing)		35%		40%		45%		50%		Other, please specify		
			Failed		50%		55%		60%		>60%		Other, please specify		

It No.	Types of Railway Bridge Defects	Measuring Unit	Bridge Defect Severity	Defect Size									
17	Anchor Damage for Bearing	Out of 100% of whole Bearing	**New Condition**	0%	2.50%	5%	7.50%	Other, please specify	
			Minor Defect (Partial corrosion)	7.50%	10%	15%	20%	Other, please specify	
			Moderate Defect (Anchor blots are partially broken or corroded on metal bearing)	20%	25%	30%	35%	Other, please specify	
			Sever Defect (Anchor bolts are broken in wide range which loses anchoring functions on metal bearing)	35%	40%	45%	50%	Other, please specify	
			Failed	50%	55%	60%	>60%	Other, please specify	
18	Bed-Damage for Bearing	Out of 100% of whole Bearing	**New Condition**	0%	2.50%	5%	7.50%	Other, please specify	
			Minor Defect (Partial cracking or spalling, excessive accumulation of dirt and debris on bearing beds)	7.50%	10%	15%	20%	Other, please specify	
			Moderate Defect (Wide range cracking or spalling)	20%	25%	30%	35%	Other, please specify	
			Sever Defect (Major splitting of bearing block, which loses bearing function on high block type bed)	35%	40%	45%	50%	Other, please specify	
			Failed	50%	55%	60%	>60%	Other, please specify	
19	Unusual Movement for Bearing	Out of 100% of whole Bearing	**New Condition**	0%	2.50%	5%	7.50%	Other, please specify	
			Minor Defect (Slight unusual clearance)	7.50%	10%	15%	20%	Other, please specify	
			Moderate Defect (Unusual clearance, which reduces rotating of sliding function)	20%	25%	30%	35%	Other, please specify	
			Sever Defect (Excessive and unusual clearance from the original place)	35%	40%	45%	50%	Other, please specify	
			Failed	50%	55%	60%	>60%	Other, please specify	
Damage Rating for Steel Girder									
20	Deformation / Deflection	mm	**New Condition**	0.00	0.25	0.50	0.75	Other, please specify	
			Minor Defect (Partial deformation on secondary members)	1.00	1.50	2.00	2.50	Other, please specify	
			Moderate Defect (Partial deformation on primary members)	3.00	3.50	4.00	4.50	Other, please specify	
			Sever Defect (Outstanding deformation, which affects the loading capacity due to buckling or partial yielding)	5.00	5.50	6.00	6.50	Other, please specify	
			Failed	7.00	7.50	8.00	> 8.00	Other, please specify	
21	Cracking	mm	**New Condition**	0.00	0.25	0.50	0.75	Other, please specify	
			Minor Defect (Spot cracking on secondary members)	1.00	1.50	2.00	2.50	Other, please specify	
			Moderate Defect (Spot cracking on primary bridge components)	3.00	3.50	4.00	4.50	Other, please specify	
			Sever Defect (Cracking on primary members, especially in welded parts)	5.00	5.50	6.00	6.50	Other, please specify	
			Failed	7.00	7.50	8.00	> 8.00	Other, please specify	
22	Corrosion	cm^2	**New Condition**	0.00	100.00	200.00	300.00	Other, please specify	
			Minor Defect (Partial corrosion on secondary members)	400.00	530.00	660.00	800.00	Other, please specify	
			Moderate Defect (Partial corrosion on primary member)	1,000.00	1,160.00	1,320.00	1,500.00	Other, please specify	
			Sever Defect (Major corrosion, which affects the loading capacity by reducing cross sectional area on primary member)	1,700.00	2,130.00	2,560.00	3,000.00	Other, please specify	
			Failed	3,500.00	4,000.00	4,500.00	> 5000.00	Other, please specify	
23	Wearing	cm^2	**New Condition**	0.00	100.00	200.00	300.00	Other, please specify	
			Minor Defect (which affects the durability of secondary members)	400.00	530.00	660.00	800.00	Other, please specify	
			Moderate Defect (which affects the durability of primary members)	1,000.00	1,160.00	1,320.00	1,500.00	Other, please specify	
			Sever Defect (Major wearing in almost all range on bridge components, which affects the durability of primary and secondary members)	1,700.00	2,130.00	2,560.00	3,000.00	Other, please specify	
			Failed	3,500.00	4,000.00	4,500.00	> 5000.00	Other, please specify	
24	Bolt Missing	each	**New Condition**	0.00	1.00	2.00	3.00	Other, please specify	
			Minor Defect (on joints)	1.00	2.00	3.00	4.00	Other, please specify	
			Moderate Defect (on a secondary member joints)	3.00	4.00	5.00	6.00	Other, please specify	
			Sever Defect (on a primary member joints)	3.00	4.00	5.00	6.00	Other, please specify	
			Failed	5.00	6.00	7.00	> 7.00	Other, please specify	
25	Paint Peel off	cm^2	**New Condition**	0.00	100.00	200.00	300.00	Other, please specify	
			Minor Defect (which affects the steel durability, but without corrosion)	400.00	530.00	660.00	800.00	Other, please specify	
			Moderate Defect (which affects the steel durability, together with corrosion)	1,000.00	1,160.00	1,320.00	1,500.00	Other, please specify	
			Sever Defect (Peel off of paint almost all of area, which affects the steel durability, together with serious corrosion)	1,700.00	2,130.00	2,560.00	3,000.00	Other, please specify	
			Failed	3,500.00	4,000.00	4,500.00	> 5000.00	Other, please specify	

Topic # 5: Personnel Qualifications:

1. Personnel in a crew involved in railway bridge inspection should include (more than one may be considered)

☐ Bridge Inspection Team Leader ☐ Bridge Coordinator ☐ Bridge Engineer
☐ Bridge Inspector ☐ Bridge Inspector Assistant
☐ Other (please specify)_____

2. What is the typical size and composition of an inspection team?

☐ A Team Leader, Bridge Coordinator, Bridge Engineer and Bridge Inspector
☐ Team Leader, Bridge Engineer and Bridge Inspector
☐ Bridge Engineer, Bridge Inspector, Assistant Bridge Inspector
☐ Others (please specify)_____

3. Are personnel involved in Bridge inspection formally Certified / Licensed?

☐ No ☐ Yes. ☐ Others (please specify)_____

4. If yes, who certified them?

☐ Ethiopian Railway Corporation ☐ Ethiopian Roads Authority ☐ Ministry of Housing construction Development Ministry ☐ Others (please specify)_____

5. Are, educational and physical, qualifications required of inspectors?

☐ No ☐ Yes. ☐ If yes, what are the requirements (please specify)_____

6. If yes on Question No. 5 Who sets these requirements?

☐ Ethiopian Railway Corporation ☐ Ethiopian Roads Authority ☐ Ministry of Housing construction Development Ministry ☐ Others (please specify)_____

7. Are these requirements used throughout the country?

☐ Yes ☐ No ☐ Each bridge owners have their own requirements

8. Is there any training for bridge inspectors working in Authorities which administer bridges?

☐ Yes ☐ No ☐ Other (please specify)_____

9. How often are the inspectors trained?

☐ Semi-annually ☐ Annually ☐ Every 2 Years ☐ Every 5 Years

☐ Other (please specify)_____

10. Who trains them?

☐ Ethiopian Railway Corporation ☐ Ethiopian Roads Authority ☐ Ministry of Housing construction Development Ministry Others (please specify)_____

Topic # 6: Equipment:

1. Facilities employed for **Bridge Inspection** (more than one can be needed)

☐ Furnished office for Bridge Inspection Personnel's

☐ Computer, Printer and Other office tools

☐ Inspection formats, Guidelines and different Bridge Inspection Manuals

☐ High-rail cars (to ride both on highway and rail environments)

☐ Inspector's safety (protective) equipment's

☐ Different measuring Equipment's

☐ Other, please specify_____

2. Facilities employed for **Bridge Inventory** (more than one can be needed)

☐ Furnished office for Bridge Inspection Personnel's

☐ Computer, Printer and Other office tools

☐ Inventory formats, Guidelines and different Bridge Inspection Manuals

☐ High-rail cars (to ride both on highway and rail environments)

☐ Inspector's safety (protective) equipment's

☐ Different measuring Equipment's

☐ Other, please specify_____

3. Is any nondestructive evaluation, nondestructive testing, or other advanced testing equipment used during bridge inspection?

☐ No ☐ Yes If Yes, please specify type of equipment use_____

_____

4. What remote monitoring technologies (if any) are being used to monitor bridges?

☐ Scour Monitoring ☐ Strain Gauges ☐ Tilt Sensors ☐ Accelerometer

☐ Other, please specify_____

Topic # 7: Documentation:

1. Do standard inventory and inspection formats available?

☐ No ☐ Yes.

2. If yes, for which types of inspection do the formats exist?

☐ Initial ☐ Visual (Regular) ☐ Detail (Major) ☐ Special (Emergency)

☐ Verification ☐ Fracture Critical ☐ Underwater Inspection ☐ Other (please specify)_____

3. Does your agency maintain manual, or guidance for bridge inspection?

☐ Yes ☐ No

4. If your answer for No. 3 is Yes, please specify_____

5. Does your agency record and store information collected from informal sources outside of the bridge inspection program?

☐ Yes ☐ No

6. If your answer for No. 5 is Yes, please specify_____

7. What is the process of distribution, review and evaluation of inspection reports?

_____

_____

8. Who reviews the inspection reports?

☐ Bridge Inspection Coordinator ☐ Bridge Engineer ☐ Bridge Inspector

☐ Other, please specify_____

Topic # 8: General Comments

1. What are the barriers that need to be overcome to implement Bridge Asset Management use?

☐ Lack of staff ☐ Lack of dedicated funding ☐ Lack of training

☐ Lack of support by upper management ☐ Other, please explain_____

2. Are you satisfied with the bridge management of other Organizations in our country?

☐ Not Satisfied ☐ Partially Satisfied ☐ Fully Satisfied If fully satisfied; please specify the name of the Organizations

_____

3. If not, how could (do you think) the bridge asset management system be improved?

_____

Appendix D

Sample Inventory Format

BD 205b (12/90)

NEW YORK STATE DEPARTMENT OF TRANSPORTATION

STRUCTURES DESIGN AND CONSTRUCTION DIVISION

BRIDGE DATA SYSTEMS

BRIDGE INVENTORY FORM RECORD CODES 01, 02, 03

REQUIRED		
REG	CO	BRIDGE IDENT. NUMBER
1	2	3 9

ALWAYS ENTER
TX CODE, COL. 120:
2=Update, 3=Create

ACTION		
	☐ Preliminary Original	Contract No.
	☐ Preliminary Copy	Letting Date
	☐ Final Original	Opening Date
TYPE INVENTORY	☐ New	Prepared By Date
	☐ Replacement	
	☐ Rehabilitation	Reviewed By Date
	☐ Update	

BRIDGE IDENTIFICATION TRANSACTION

LOCAL BRIDGE NO.	POLIT. UNIT	LATITUDE DEG.	LATITUDE MIN.	LONGITUDE DEG.	LONGITUDE MIN.	LOCATION	DO	OWNER	MAINT. RESPONS.
13 17	18 21	22	24 26	27 29	30 32	33 57	58	59 61	63 65

FUND	TYPE SVC.	MAP NO.	PLANS	HYDRO	ORIGINAL CONTRACT NO.	YEAR BUILT	LAST RECON	ACCU	ORDER NO.	YEAR ACQ.	RAMPS ONLY - ATTACH. TO: BIN	RAMPS ONLY - ATTACH. TO: SPAN NO	H S	CRIT. F	REQUIRED CONT CODE	REQUIRED REC CODE	REQUIRED TX CD
68	69 70	71 74	75	76	77 86	87 90	91 92	93	94 98	99 102	103 109	110 112	113	114	116	118	120
																01	

STRUCTURAL TRANSACTION

GEN TYP MAIN SPAN	GEN TYP APPR. SPAN	NO MAIN SPANS	NO. APPR. SPANS	NO. OF RAMPS	DESN LOAD	LENGTH MAX SPAN	TOTAL BRIDGE LENGTH	APPR. ROAD WIDTH	OUT TO OUT WIDTH	OUT TO OUT VAR.	CURB CURB WIDTH	CURB VAR.	CURB TYPE LT	CURB TYPE RT	SIDEWALK LEFT WIDTH	SIDEWALK LEFT TY	SIDEWALK RIGHT WIDTH	SIDEWALK RIGHT TY	MEDIAN WIDTH	MEDIAN TYPE
13 15	16 18	19 21	22 25	26	28	30 33	34 38	39 41	42 45	46	47 50	51	52	53	54 56	57	58 60	61	62 64	65

BEGINNING ABUTMENT ABUT	BEGINNING ABUTMENT WW	BEGINNING ABUTMENT FTG	BEGINNING ABUTMENT PILE	BEGINNING ABUTMENT HT. (FT)	BEGINNING ABUTMENT SKEW ANG.	BEGINNING ABUTMENT JOINT TYPE	BEGINNING ABUTMENT SLOPE	ENDING ABUTMENT ABUT	ENDING ABUTMENT WW	ENDING ABUTMENT FTG	ENDING ABUTMENT PILE	ENDING ABUTMENT HT. (FT)	ENDING ABUTMENT SKEW ANG.	ENDING ABUTMENT JOINT TYPE	ENDING ABUTMENT SLOPE	BRIDGE DECK AREA (SQ. FT.)	RADIUS	T.S.D.	REQUIRED CONT CODE	REQUIRED REC CODE	REQUIRED TX CD
66	67	68	69	70	72	74	76	77	78	79	80	81	83	85	87	88 95	96 99	100	116	118	120
																				02	

SAFETY AND UTILITY TRANSACTION

GUIDE RAIL TYPE	GUIDE RAIL TRANS	GUIDE RAIL TERM	CURB TRANS	ALIGN	MED BAR	RAIL TYPE LT	RAIL TYPE RT	GORE	ATTN	UTILITIES 1	2	3	4	5	6	7	8	LIGHTS ST	LIGHTS ON	LIGHTS UN	REQUIRED CONT CODE	REQUIRED REC CODE	REQUIRED TX CD
13	15	17	19	21	22	24	26	28	29	30	32	34	36	38	40	42	44	46	47	48	116	118	120
																						03	

BD 205b — BLUE

New York State Department of Transportation, Bridge Inventory format

Ethiopian Roads Authority Bridge Inventory Format [6]

BRIDGES INVENTORY FORMAT

RNMD	SECTION	ROAD SEGMENT	ROAD CLASS	BRIDGE NAME	ROAD NUMBER	BRIDGE NO	Coordnates
							X =
							Y =

IT.NO.	GENERAL INFORMATION		SUPER STRUCTURE		SUBSTRUCTURE AND FOUNDATION		COMPONENTS AND ANCILLARIES	
1	LOCATION (KM , FROM ADDIS)		BRIDGE / STRUCTURE TYPE		ABUTMENT TYPE A1		TYPE OF EXPANSION JOINT	
2	BRIDGE LENGTH ,Mt		NO OF SPAN		ABUTMENT TYPE A2		TYPE OF GUARD RAILING	
3	BRIDGE WIDTH ,Mt		SPAN COMPOSITION		HEIGHT OF ABUTMENT A1,mt		TYPE OF ABUTMENTS BEARING	
4	RIVER WIDTH, Mt		TOTAL SPAN LENGTH ,Mt		WIDTHOF ABUTMENT A1, Mt		TYPE OF PIERS BEARING	
5	PRESENT WATER LEVEL		CARRIAGE WAY WIDTH, Mt		HEIGHT OF ABUTMENT A2,mt		TYPE OF SURFACE	
6	HIGHEST WATER LEVEL		SIDE WALK WIDTH, Mt		WIDTHOF ABUTMENT A2 , Mt			
7	AREA TOPOGRAPHY		NO. OF LANE		WING WALL LENGTH,Mt			
8	YEAR OF CONSTRUCTION		SPAN SUPPORT TYPE		TYPE OF PIERS			
9	CONTRACTOR		DECK SLAB TYPE		NO. OF PIERS			
10	DESIGNER / SUPERVISOR		SLAB THICKNESS, cm		HEIGHT OF PIER 1,2,3 …			
11	COST OF THE BRIDGE, Br		NO. OF GIRDER / BOX		WIDTHOF PIERS 1,2,…			
12	LOAD CAPACITY, Ton		DEPTH OF GIRDER / BOX		TYPE OF ABUTMENT FOUNDATION			
13	AVERAGE DAILY TRAFFIC		SPACING OF GIRDER ,Mt		TYPE OF PIER FOUNDATION			
14	DETOUR POSSIBILITY , Y / N		WIDTH OFGIRDER/ BOX ,Mt		ABUTMENT FOUNDATION SIZE			
15	ROAD ALIGNMENT, CURVE / STRAIGHT				PIER FOUNDATION SIZE			
16	ALTITUDE , Mt				NO.OF ABUTMENT PILES			
17	SAFETY/LOAD LIMIT SIGN, Y/ N				NO.OF PIER PILES			
18					ABUTMENT PILE DEPTH			
19					PIER PILE DEPTH			
20					SOIL TYPE			

shaded

TYPES TO BE SELECTED FROM TABLE (see backpage)

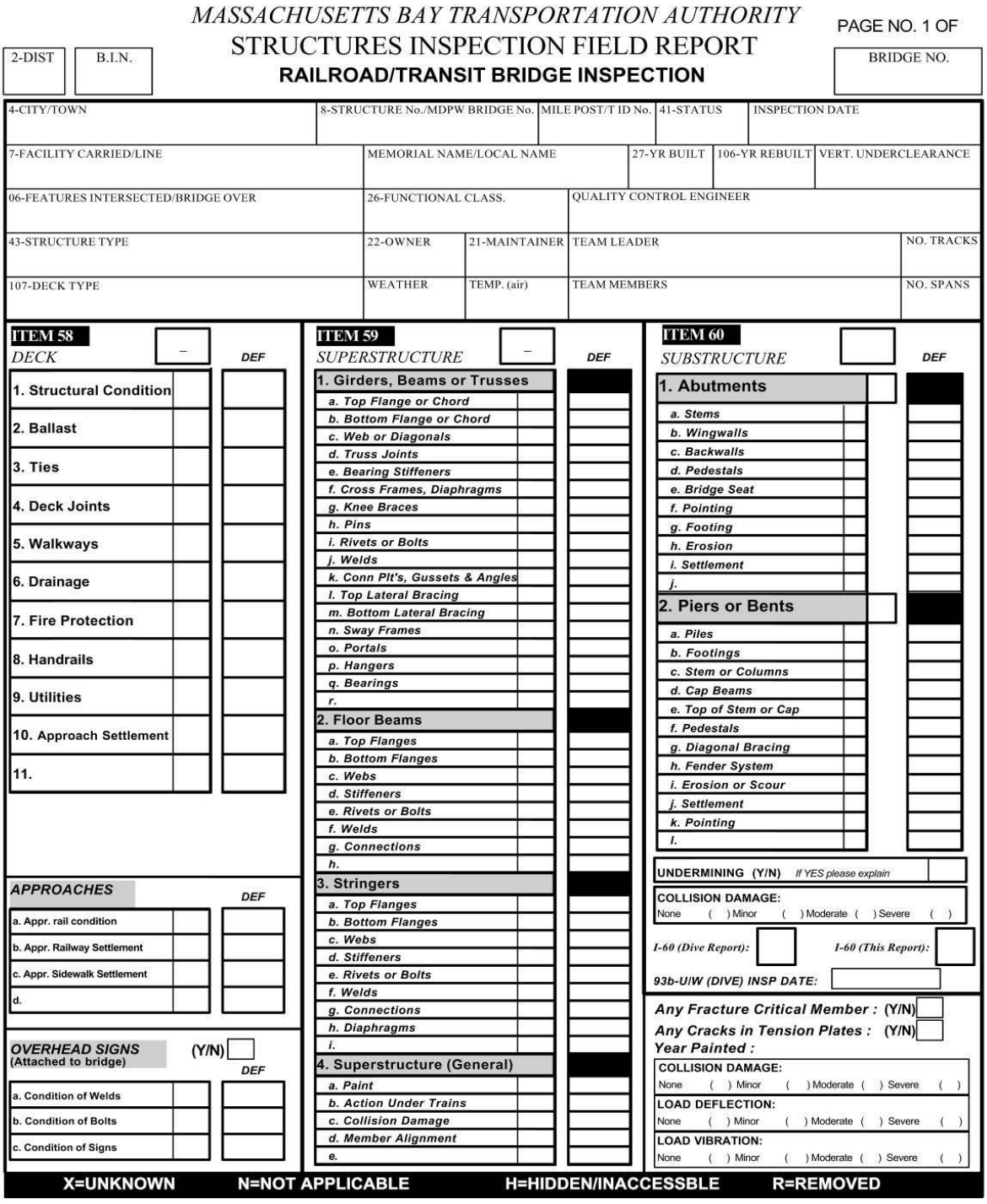
INSPECTOR ……

Approved ……

Date ……

Appendix E

Sample Inspection Format



MASSACHUSETTS BAY TRANSPORTATION AUTHORITY

STRUCTURES INSPECTION FIELD REPORT

RAILROAD/TRANSIT BRIDGE INSPECTION

PAGE NO. 1 OF

2-DIST | B.I.N. | BRIDGE NO.

4-CITY/TOWN	8-STRUCTURE No./MDPW BRIDGE No.	MILE POST/T ID No.	41-STATUS	INSPECTION DATE

7-FACILITY CARRIED/LINE	MEMORIAL NAME/LOCAL NAME	27-YR BUILT	106-YR REBUILT	VERT. UNDERCLEARANCE

06-FEATURES INTERSECTED/BRIDGE OVER	26-FUNCTIONAL CLASS.	QUALITY CONTROL ENGINEER

43-STRUCTURE TYPE	22-OWNER	21-MAINTAINER	TEAM LEADER	NO. TRACKS

107-DECK TYPE	WEATHER	TEMP. (air)	TEAM MEMBERS	NO. SPANS

ITEM 58 *DECK* – DEF

		DEF
1. Structural Condition		
2. Ballast		
3. Ties		
4. Deck Joints		
5. Walkways		
6. Drainage		
7. Fire Protection		
8. Handrails		
9. Utilities		
10. Approach Settlement		
11.		

APPROACHES

		DEF
a. Appr. rail condition		
b. Appr. Railway Settlement		
c. Appr. Sidewalk Settlement		
d.		

OVERHEAD SIGNS (Attached to bridge) (Y/N)

		DEF
a. Condition of Welds		
b. Condition of Bolts		
c. Condition of Signs		

ITEM 59 *SUPERSTRUCTURE* – DEF

		DEF
1. Girders, Beams or Trusses		
a. Top Flange or Chord		
b. Bottom Flange or Chord		
c. Web or Diagonals		
d. Truss Joints		
e. Bearing Stiffeners		
f. Cross Frames, Diaphragms		
g. Knee Braces		
h. Pins		
i. Rivets or Bolts		
j. Welds		
k. Conn Plt's, Gussets & Angles		
l. Top Lateral Bracing		
m. Bottom Lateral Bracing		
n. Sway Frames		
o. Portals		
p. Hangers		
q. Bearings		
r.		
2. Floor Beams		
a. Top Flanges		
b. Bottom Flanges		
c. Webs		
d. Stiffeners		
e. Rivets or Bolts		
f. Welds		
g. Connections		
h.		
3. Stringers		
a. Top Flanges		
b. Bottom Flanges		
c. Webs		
d. Stiffeners		
e. Rivets or Bolts		
f. Welds		
g. Connections		
h. Diaphragms		
i.		
4. Superstructure (General)		
a. Paint		
b. Action Under Trains		
c. Collision Damage		
d. Member Alignment		
e.		

ITEM 60 *SUBSTRUCTURE* DEF

		DEF
1. Abutments		
a. Stems		
b. Wingwalls		
c. Backwalls		
d. Pedestals		
e. Bridge Seat		
f. Pointing		
g. Footing		
h. Erosion		
i. Settlement		
j.		
2. Piers or Bents		
a. Piles		
b. Footings		
c. Stem or Columns		
d. Cap Beams		
e. Top of Stem or Cap		
f. Pedestals		
g. Diagonal Bracing		
h. Fender System		
i. Erosion or Scour		
j. Settlement		
k. Pointing		
l.		

UNDERMINING (Y/N) *If YES please explain*

COLLISION DAMAGE:
None ( ) Minor ( ) Moderate ( ) Severe ( )

I-60 (Dive Report): *I-60 (This Report):*

93b-U/W (DIVE) INSP DATE:

Any Fracture Critical Member : (Y/N)

Any Cracks in Tension Plates : (Y/N)

Year Painted :

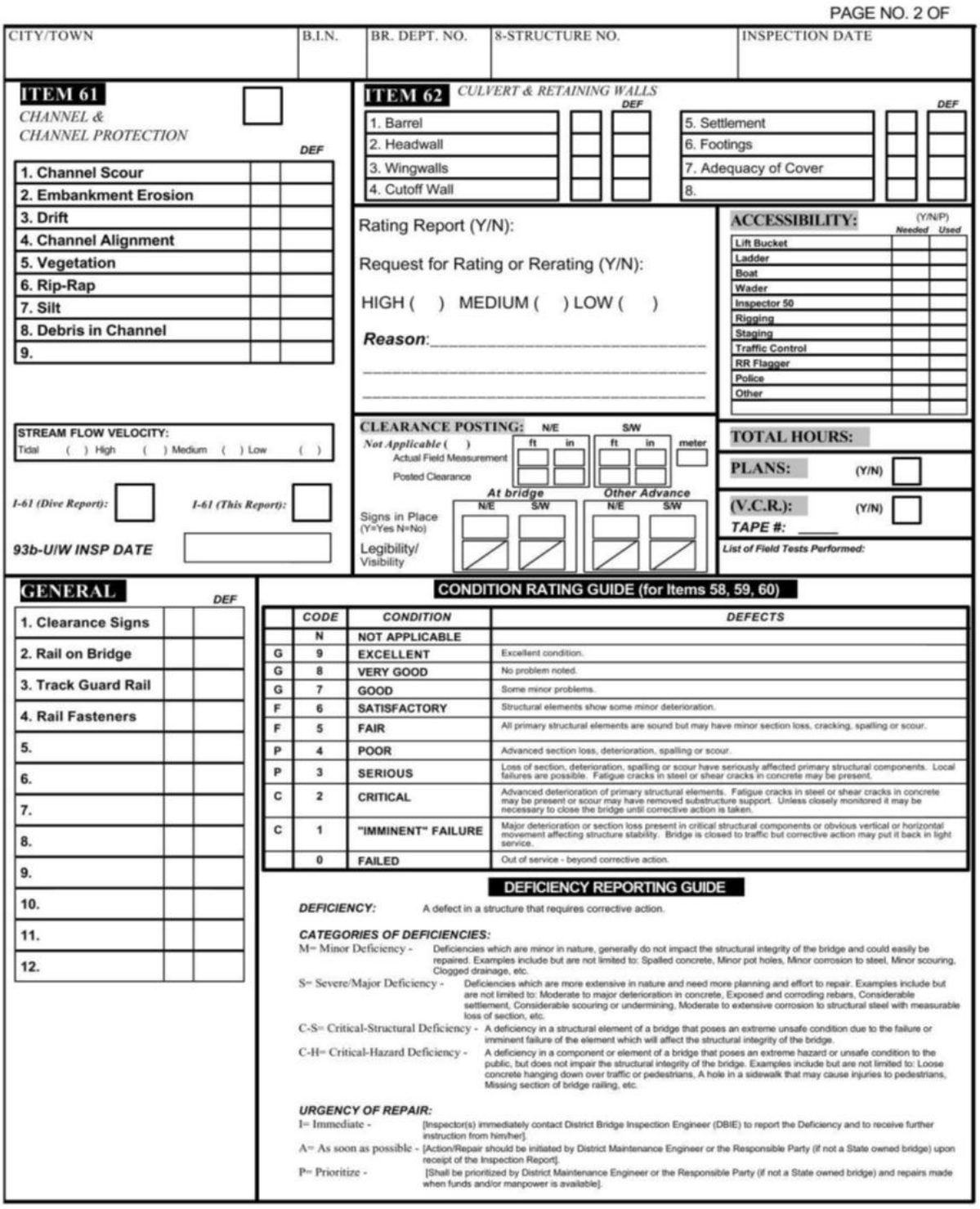
COLLISION DAMAGE:
None ( ) Minor ( ) Moderate ( ) Severe ( )

LOAD DEFLECTION:
None ( ) Minor ( ) Moderate ( ) Severe ( )

LOAD VIBRATION:
None ( ) Minor ( ) Moderate ( ) Severe ( )

X=UNKNOWN **N=NOT APPLICABLE** **H=HIDDEN/INACCESSBLE** **R=REMOVED**

Massachusetts Bay Transportation Authority Railroad/Transit Inspection Form [14]



PAGE NO. 2 OF

CITY/TOWN	B.I.N.	BR. DEPT. NO.	8-STRUCTURE NO.	INSPECTION DATE

ITEM 61 *CHANNEL & CHANNEL PROTECTION*

	DEF
1. Channel Scour	
2. Embankment Erosion	
3. Drift	
4. Channel Alignment	
5. Vegetation	
6. Rip-Rap	
7. Silt	
8. Debris in Channel	
9.	

ITEM 62 *CULVERT & RETAINING WALLS*

	DEF		DEF
1. Barrel		5. Settlement	
2. Headwall		6. Footings	
3. Wingwalls		7. Adequacy of Cover	
4. Cutoff Wall		8.	

Rating Report (Y/N):

Request for Rating or Rerating (Y/N):

HIGH ( ) MEDIUM ( ) LOW ( )

Reason:_____

ACCESSIBILITY: (Y/N/P)

	Needed	Used
Lift Bucket		
Ladder		
Boat		
Wader		
Inspector 50		
Rigging		
Staging		
Traffic Control		
RR Flagger		
Police		
Other		

STREAM FLOW VELOCITY:
Tidal ( ) High ( ) Medium ( ) Low ( )

I-61 (Dive Report): ☐ ***I-61 (This Report):*** ☐

93b-U/W INSP DATE _____

CLEARANCE POSTING:

	N/E ft	N/E in	S/W ft	S/W in	meter
Not Applicable ( ) Actual Field Measurement					
Posted Clearance					

	At bridge N/E	At bridge S/W	Other Advance N/E	Other Advance S/W
Signs in Place (Y=Yes N=No)				
Legibility/ Visibility				

TOTAL HOURS:

PLANS: (Y/N) ☐

(V.C.R.): (Y/N) ☐

TAPE #: _____

List of Field Tests Performed:

GENERAL

	DEF
1. Clearance Signs	
2. Rail on Bridge	
3. Track Guard Rail	
4. Rail Fasteners	
5.	
6.	
7.	
8.	
9.	
10.	
11.	
12.	

CONDITION RATING GUIDE (for Items 58, 59, 60)

	CODE	CONDITION	DEFECTS
	N	NOT APPLICABLE	
G	9	EXCELLENT	Excellent condition.
G	8	VERY GOOD	No problem noted.
G	7	GOOD	Some minor problems.
F	6	SATISFACTORY	Structural elements show some minor deterioration.
F	5	FAIR	All primary structural elements are sound but may have minor section loss, cracking, spalling or scour.
P	4	POOR	Advanced section loss, deterioration, spalling or scour.
P	3	SERIOUS	Loss of section, deterioration, spalling or scour have seriously affected primary structural components. Local failures are possible. Fatigue cracks in steel or shear cracks in concrete may be present.
C	2	CRITICAL	Advanced deterioration of primary structural elements. Fatigue cracks in steel or shear cracks in concrete may be present or scour may have removed substructure support. Unless closely monitored it may be necessary to close the bridge until corrective action is taken.
C	1	"IMMINENT" FAILURE	Major deterioration or section loss present in critical structural components or obvious vertical or horizontal movement affecting structure stability. Bridge is closed to traffic but corrective action may put it back in light service.
	0	FAILED	Out of service - beyond corrective action.

DEFICIENCY REPORTING GUIDE

DEFICIENCY: A defect in a structure that requires corrective action.

CATEGORIES OF DEFICIENCIES:

M= Minor Deficiency - Deficiencies which are minor in nature, generally do not impact the structural integrity of the bridge and could easily be repaired. Examples include but are not limited to: Spalled concrete, Minor pot holes, Minor corrosion to steel, Minor scouring, Clogged drainage, etc.

S= Severe/Major Deficiency - Deficiencies which are more extensive in nature and need more planning and effort to repair. Examples include but are not limited to: Moderate to major deterioration in concrete, Exposed and corroding rebars, Considerable settlement, Considerable scouring or undermining, Moderate to extensive corrosion to structural steel with measurable loss of section, etc.

C-S= Critical-Structural Deficiency - A deficiency in a structural element of a bridge that poses an extreme unsafe condition due to the failure or imminent failure of the element which will affect the structural integrity of the bridge.

C-H= Critical-Hazard Deficiency - A deficiency in a component or element of a bridge that poses an extreme hazard or unsafe condition to the public, but does not impair the structural integrity of the bridge. Examples include but are not limited to: Loose concrete hanging down over traffic or pedestrians, A hole in a sidewalk that may cause injuries to pedestrians, Missing section of bridge railing, etc.

URGENCY OF REPAIR:

I= Immediate - [Inspector(s) immediately contact District Bridge Inspection Engineer (DBIE) to report the Deficiency and to receive further instruction from him/her].

A= As soon as possible - [Action/Repair should be initiated by District Maintenance Engineer or the Responsible Party (if not a State owned bridge) upon receipt of the Inspection Report].

P= Prioritize - [Shall be prioritized by District Maintenance Engineer or the Responsible Party (if not a State owned bridge) and repairs made when funds and/or manpower is available].

Massachusetts Bay Transportation Authority Railroad/Transit Inspection Form [14]

Ethiopian Roads Authority Bridge Inspection Format for Major Inspection [6]

BRIDGES INSPECTION FORMAT

For Major Inspection

RNMD Name ..... Section ..... Road Segment ..... Bridge No ..... Bridge Name .....

IT. NO	Bridge parts	Damage type	Damage qtty by Rank			IT. NO	Bridge parts	Damage type	Damage qtty by Rank			IT. NO	Bridge parts	Damage type	Damage qtty by Rank		
	Super structure		A	B	C		**Sub Structure**		A	B	C		**Ancillaries**		A	B	C
1	**Deck Slab**	Cracking , Mt				4	**Foundation**	Cracking ,Mt				8	**Pavement**	Wave, Mt			
		Peel Off , Mt2						Peel Off ,Mt2						Rutting, Mt			
		Rebar Exposure, Mt2						Rebar Exposure , Mt2						Cracking, Mt			
		Honeycomb , Mt2						Honeycomb , Mt2						Potholes , Mt2			
		Void , Mt2						Void ,Mt2				9	**Kerb & Railing**	Cracking, Mt			
		Water Leakage , Mt2						Water Leakage , Mt2						Peel Off, Mt2			
2	**Concrete Girder/Arch**	Cracking ,Mt						Displacement						Rebar Exposure , Mt2			
		Peel Off , Mt2						Scour, Mt2						Deformation, Mt			
		Rebar Exposure, Mt2				5	**Abutment and Wingwall**	Cracking, Mt						Corrosion, Mt			
		Honeycomb ,Mt2						Peel Off / Stone deterioration, Mt2						Missing, Each			
		Void , Mt2						Rebar Exposure , Mt2				10	**Expansion Joint**	Noise, Mt			
		Water Leakage , Mt2						Honeycomb , Mt2						Water Leakage, Mt			
								Void ,Mt2						Deformation, Mt			
3	**Steel Girder**	Deformation , Mt						Water Leakage , Mt2						Peel Off, Mt			
		Cracking , Mt						Displacement / Bulging ,Mt2						Missing, Mt			
		Corrosion , Mt2						Scour , Mt2				11	**Bearing**	Main Damage, Each			
		Wearing , Mt2				6	**Embankment**	Depression , Mt2						Parts missing, Each			
		Bolt Missing , Each						Erosion , Mt2						Anchor Damage, Each			
		Paint Peel off ,Mt2				7	**Rip rap**	Missing, Each						Bed Damage, each			
	Hydrology defects							Erosion, Mt2						Unusual movement, Each			
	Water Way adequacy (Over flooding, Siltation, Scouring,...)							Displacement, Mt2				12	**Drainage**	Pipe Damage , Each			
	Yes **No**													Blocked, Each			
														Inlet Damage, each			

Inspection date .....

Inspectors name and signature .....

COMPAGNIE DU CHEMIN DE FER FRANCO-ETHIOPIEN DE DJIBOUTI A ADDIS-ABEBA

PONTS MÉTALLIQUES

PROCÈS-VERBAL

d'inspection périodique et de vérification des flèches permanentes

Section

Ligne d

Point kilométrique:

Pont à travée

de mètres d'ouverture, établi sur

Nom du Chef de Section qui a dirigé l'Inspection:

Date de l'Inspection:

Renseignements sur l'état des différentes parties de l'ouvrage:

Mode d'assemblage:

Maîtresses poutres:

Pièces de pont:

Longerons:

Contreventement:

Appareils d'appuis:

Sommiers:

Superstructure (1) et platelage:

Culées et piles:

Fondations:

État général de la rivure ou de la soudure:

Peinture (date de la dernière peinture):

VÉRIFICATION des FLÈCHES PERMANENTES et NIVELLEMENT des APPUIS

Repère et Nivellement (*description, emplacement, côte, croquis*)	
Indication des points nivelés pour la mesure des flèches permanentes	
Indication de la position des points choisis pour le nivellement des appuis	
Température au moment du nivellement	

Croquis

Ethio-Djibouti Railway Company Bridge Inspection Format in French language

Company Franco-Ethiopia Railway Djibouti Addis Ababa

Metallioues Bridges

Minutes of Periodic Inspection

Section:_____

Line of :_____ **to** _____

Km:_____ **to** _____

Name of the Section Chief who headed Inspction:_____

The Head of Division:_____

Date of Visit	Short Designation of Composition, Nature, Opening etc.	Againist-Windpost	Bearing	Bases	Superstructure and Deck	Abutments and Piles	Foundation	Welding	Painting	Observation on General State and Repair Work

Ethio-Djibouti Railway Company Bridge Inspection Format in English

Tally book of track inspection

E/AALRT 0030-03-B2

Name of track: _____ Start-stop mileage: From _____ km to _____ km, station track: _____

Radius of curve _____ m Super elevation_____ mm slope rate____‰ total track length:_____ km

Inspection date	Serial number of rail																					
	Inspection item	1				2				3				4								
		Joint	ZH▽			Joint	HY▽		YH▽	Joint	HZ▽			Joint				Joint		Middle		
	Gauge	1	2	1	0	1	0	0	1	2	2	1	8—	1	0	10 — — √	1					
	Horizontal twist of track.	8—	2	-1	-4	4	2	2	1	2	0	-3	4	2	2	12 — — √	2					
	Note	√△8mm △7mm Expired maintenance: 1 position at gauge, 1 position at level and 1 position at twist of track. Expired urgent repair: 1 position at gauge, 1 position at level and 1 position at twist of track. The content of urgent repair: For expired urgent repair; eliminate 1 position at gauge, 1 position at level and 1 position at twist of track. For expired maintenance; in total, 38 pcs of changing gauge and 40 pcs for pad level, return inspection, 1 position at gauge and 1position at level without twist of track. Team leader: Date:																					
	Gauge																					
	Horizontal twist of track.																					
	Note																					

Sample AALRT Track Inspection Format [25]

ADISS ABABA EW & NS (LINE PHASE 1) LRT PRJECT

EAST WEST LINE TRACK CHECKING RECORD

			A(very much serious)			B(very serious)			C(serious)			D(less serious)		
East West left			left level >10	left profile >10	left gauge >10 or <-6	left level >9	left profile >9	left gauge >9 or <-5	left level >7	left profile >7	left gauge >8 or <-4	left level >6	left profile >6	left gauge >7 or <-3
EWZK9+510	2349.975	2349.975												
EWZK9+520	2349.955	2349.955												
EWZK9+530	2349.935	2349.935												
EWZK9+540	2349.915	2349.915												
EWZK9+550	2349.895	2349.895												
EWZK9+560	2349.875	2349.875												
EWZK9+570	2349.855	2349.855												
EWZK9+580	2349.835	2349.835												
EWZK9+590	2349.815	2349.815												
EWZK9+600	2349.795	2349.795												
EWZK9+610	2349.753	2349.753												
EWZK9+620	2349.671	2349.671												
EWZK9+630	2349.549	2349.549												
EWZK9+640	2349.393	2349.393												
EWZK9+650	2349.233	2349.233												
EWZK9+660	2349.073	2349.073												
EWZK9+670	2348.913	2348.913												

Explanation	Check Frequency: routine examination once a month , including gauge , horizontal , triangular pits.
	Single pitch: 10 m line segments , 5 m curve segment , increased positive vector examinations , see the curve section in the checklist .
	To rail , and the level of rail , fastening state while fully observed in line static checking , exception credited remarks column .
	Left and right above the rail track when referred to as "+" , the right rail is higher than left rail as " - ."

Appendix F

Facilities used for Inspection

SR	INSTRUMENTS	PURPOSE
1	Inspection and Inventory report formats, notebook and clipboard	to record findings
2	high visibility vest, safety boots and waterproof boots, gloves, both leather and plastic	personal protective equipment
3	first aid kit	in case of accidents for emergency works
4	signage	for traffic management purposes as required
5	crack gauge	to measure crack width
6	GPS unit	to read location / coordinate
7	Chalk and permanent marker pens	
8	wire brush	to clean
9	radio unit and mobile phone	to communicate
10	30M Steel tape	For taking measurements such asclear span, overall length of girder,etc.
11	Straight edge (1M Long)	For checking deformation, distortion, buckling and bulging of structure
12	Feeler Gauge (0.1 to 5mm)	For measureming width of cracks and cavity
13	Measuring microscope	For measuring invisible minute crack width by magnification scale.
14	Nylon cord or Piano wire with clamp and 2 nos. 10kg. weight	For measuring camber of PSC girder.
15	15 Cm steel scale	For measuring depth of spalled concrete and gap between parts.
16	Mirror (10 x 15 Cm)	For inspecting parts in any awkward location by reflection method and to lit object in dark location by directing sun rays.
17	Magnifying glass (100mm dia)	For identifying very fine cracks in member/ welds which may not be visible for naked eyes.
18	Torch light (5 cell)/ Flash light	Used along with morror for identification of fine cracks in dark locations.
19	Plumb bob	For checking verticality of member , pier and abutment etc.
20	Inspection cum chipping hammer	For checking hollow pocket or honey comb in masonry and concrete structure including PSC girder by tapping and for examining the extent of corrosion, adherence of paint and removing loose disintegrated material during inspection.
21	Thermometer	For recording temperature at the time of measuring camber and for purpose of setting bearings at desired inclination.
22	Spirit level	For checking cross level of track on bridge or bed block. Also for setting of girders on bearing.
23	Chalk marker, plaster of Paris, Red Paint, Plain glass	To mark the cracks on concrete structure and make tel-tale for observing crack.
24	Binoculars	For inspection of bridge components which are at inaccessible location tall piers, arches in viaducts, etc. prior to closer examination.
25	Camera with flash	For taking photograph of cracks, spalled concrete or any distressed portion for clarity and record.
26	Pocket knife	For removing scaled or weathered surface of concrete for inspection.

27	Dial Gauge	For measurement of deflection in case of load testing or to measure depth of cavity.
28	Schmidt's rebound hammer for concrete	For assessing the strength of concrete structure for soundness as NDT method.
29	Concrete cover meter (R meter)	For assessing the cover availability to reinforcement in existing concrete structure or diameter of steel bar or spacing.
30	Ultrasonic pulse velocity test	To identify uniform dense concrete structure or hollow/ honey comb inside the concrete structures and to determine presence of discontinuity, crack etc.
31	Windsor probe test	To evaluate the hardness of concrete by probing and penetration, which will help in assessing compressive strength of concrete.
32	CORE drilling test	To determine actual strength of concrete in structure.
33	Scaffolding/Inspection cradle	To provide close assessibility to structure for inspection of girder, sub structure etc.

Equipment's required for Inspection of Bridge [2, 17 & 18]

Appendix G

Response summary of Bridge Defects and their Severity by Bridge Professional

Bridge Defects / Damages

Table: Response summary of Bridge Defects / Damages by Bridge Professional

Item Description	Bridge Professionals	
Which of the following bridge defects / damages are common to your practice?	Cracking, Peel Off, Rebar Exposure, Steel Corrosion, Steel Deformation, Steel Paint Peel off, Bolt Missing, Honeycomb, Spalling, Delamination, Material Deterioration, Void, Water Leakage, Efflorescence, Foundation, Abutment & Wing wall Settlement, Inclination, Scour, Siltation, Over flooding, Stone deterioration, Bulging, Embankment Depression, Embankment Erosion, Missing, Noise, Excessive Vibration, Bearing Main Damage, Bearing Parts missing, Bearing Anchor Damage, Bearing Bed Damage, Bearing Unusual movement, Bearing Dislocation, Pipe Damage, Pipe Blocked, Pipe Inlet Damage, Track Undulation, Rail Wearing, Fastener Damage, Ballast Loss and Sleeper Damage	
How do you rate Extent of bridge defect / damage?	No Significant defect, Slight, Moderate, Wide and Extensive	
What could be the percentages of the extent of bridge defects compared with the whole dimensions of bridge elements?	No significant defect	≤ 2%
	Slight Defect	≤ 7%
	Moderate Defect	≤ 13%
	Moderate Defect	≤ 29%
	Extensive Defects	≤ 49%
How do you rate Degree/ Severity of defect/Damage?	Failed, Sever, Moderate, Minor, New	
How do you rate Relevancy of defect / damage?	No significant, Minor, Moderate, Major, Critical	
How do you rate Relevancy of defect / damage out of the whole Bridge?	No significant	5%
	Minor	9%
	Moderate	15%
	Major	27%
	Critical	44%
What could be the % age Importance be for defects on railway bridge elements out of 100% of whole Bridge?	Substructure	38%
	Superstructure	35%
	Railway Track Structure over the bridge	18%
	Bridge Ancillary	9%
What could the % age Importance be for defects on railway bridge Superstructure elements out of 100% of whole RC Superstructure elements?	Deck Slab	37%
	Deck Girder	63%
What could the % age Importance be for defects on railway bridge Steel Superstructure elements out of 100% of whole Steel Superstructure elements?	Steel Deck	38%
	Steel Girder	62%
What could the % age Importance be for defects on railway bridge Substructure elements out of 100% of whole Substructure elements?	Rip Rap	9%
	Embankment	11%
	Abutment & Wing wall	39%
	Pier & Foundation	41%
What could the % age Importance be for defects	Kerb, Railing & Post	17%

on Railway Bridge Ancillaries Elements out of 100% of whole Ancillaries Elements?	Deck Drains	17%
	Expansion Joint	19%
	Bearing	47%
What could the % age Importance be for defects on Railway Track Structure Elements over the bridge out of 100% of whole Railway Track Structure?	Ballast Retainers	9%
	Ballast	15%
	Rail Fasteners	15%
	Sleeper	18%
	Rail	43%
What could the % age Importance be for defects on railway bridge Deck Slab Defects out of 100% of whole Deck Slab Defects?	Honeycomb	10%
	Peel off	11%
	Void	11%
	Water Leakage	14%
	Rebar Exposure	23%
	Cracking	31%
What could the % age Importance be for defects on Railway Bridge Concrete Girder Defects out of 100% of whole Concrete Girder Defects?	Honeycomb	11%
	Peel off	11%
	Void	11%
	Water Leakage	13%
	Rebar Exposure	23%
	Cracking	31%
What could the % age Importance be for defects on Railway Bridge Steel Girder Defects out of 100% of whole Steel Girder Defects?	Paint Peel off	9%
	Bolt Missing	11%
	Wearing	13%
	Corrosion	17%
	Cracking	23%
	Deformation	27%
What could the % age Importance be for defects on Railway Bridge Pier & Foundation Defects out of 100% of whole Pier & Foundation Defects?	Void	5%
	Water Leakage	6%
	Honeycomb	7%
	Peel off / Stone Deterioration	9%
	Rebar Exposure	14%
	Displacement / Bulging	15%
	Cracking	21%
	Scour	23%
What could the % age Importance be for defects on Railway Bridge Abutment & Wing wall Defects out of 100% of whole Abutment & Wing wall Defects.	Void	6%
	Water Leakage	7%
	Honeycomb	7%
	Peel off / Stone Deterioration	10%
	Rebar Exposure	13%
	Displacement / Bulging	13%
	Cracking	22%

	Scour	22%
What could the % age Importance be for defects on Railway Bridge Embankment Defects out of 100% of whole Embankment Defects?	Depression	40%
	Erosion	60%
What could the % age Importance be for defects on Railway Bridge Rip Rap Defects out of 100% of whole Rip Rap Defects?	Displacement	31%
	Missing	34%
	Erosion	35%
What could the % age Importance be for defects on Railway Bridge Bearing Defects out of 100% of whole Bearing Defects?	Parts Missing	14%
	Anchor Damage	15%
	Bed Damage	16%
	Unusual Movement	22%
	Main Damage	33%
What could the % age Importance be for defects on Railway Bridge Expansion Joint Defects out of 100% of whole Expansion Joint Defects?	Peel off	17%
	Missing	19%
	Noise	19%
	Deformation	22%
	Water Leakage	23%
What could the % age Importance be for defects on Railway Bridge Kerb & Railing Defects out of 100% of whole Kerb & Railing Defects?	Corrosion	13%
	Peel off	14%
	Rebar Exposure	16%
	Missing	18%
	Cracking	19%
	Deformation	20%
What could the % age Importance be for defects on railway bridge Drainage Defects out of 100% of whole Drainage Defects?	Inlet Damage	26%
	Blocked	36%
	Pipe Damage	38%
What could the % age Importance be for defects on Railway Track Structure Element Defects over the bridge out of 100% of whole Railway Track Structure Elements?	Defects on Ballast Retainers	10%
	Defects on Rail Fasteners	15%
	Defects on Ballast	19%
	Defects on Sleeper	20%
	Defects on Rail	36%

Measuring Bridge Defects

Table: Response summary of Severity of bridge defects by Bridge Professionals

Bridge Defect	Rating of Bridge Defects	
Cracking	Crack width, mm	
	New	crack width shall be < 0.25
	Minor	crack width shall be < 1.00
	Moderate	crack width shall be < 3.00
	Sever	crack width shall be < 5.00
	Failed	crack width shall be > 8.00

Peel Off	**Area of Peel Off , cm^2**	
	New	Area of Peel Off shall be < 25.00
	Minor	Area of Peel Off shall be < 200.00
	Moderate	Area of Peel Off shall be < 760.00
	Sever	Area of Peel Off shall be < 1000.00
	Failed	Area of Peel Off shall be > 2200.00
Rebar Exposure	**Area of Rebar Exposure, cm^2**	
	New	Area of Rebar Exposure shall be 0.00
	Minor	Area of Rebar Exposure shall < 400.00
	Moderate	Area of Rebar Exposure shall be < 1000.00
	Sever	Area of Rebar Exposure shall be < 1700.00
	Failed	Area of Rebar Exposure shall be > 5000.00
Honeycomb	**Area of Honeycomb, cm^2**	
	New	Area of Honeycomb shall be < 100.00
	Minor	Area of Honeycomb shall be < 400.00
	Moderate	Area of Honeycomb shall be < 1000.00
	Sever	Area of Honeycomb shall be < 1700.00
	Failed	Area of Honeycomb shall be > 5000.00
Void	**Volume of Void, cm^3**	
	New	Volume of Void shall be < 33.00
	Minor	Volume of Void shall be < 600.00
	Moderate	Volume of Void shall be < 800.00
	Sever	Volume of Void shall be < 1150.00
	Failed	Volume of Void shall be > 2200.00
Water Leakage	**Area of Water Leakage, cm^2**	
	New	Area of Water Leakage shall be < 100.00
	Minor	Area of Water Leakage shall be < 400.00
	Moderate	Area of Water Leakage shall be < 1000.00
	Sever	Area of Water Leakage shall be < 2130.00
	Failed	Area of Water Leakage shall be > 5000.00
End Block Damage (Prestressed Concrete Bridge)	**Crack width of End Block Damage (Prestressed Concrete Bridge), mm**	
	New	Crack width of End Block Damage shall be 0.00
	Minor	Crack width of End Block Damage shall be < 0.50
	Moderate	Crack width of End Block Damage shall be < 2.00
	Sever	Crack width of End Block Damage shall be < 3.00
	Failed	Crack width of End Block Damage shall be > 5.00
End Bearing Plate Damage	**Area of End Bearing Plate Damage (Prestressed Concrete Bridge), cm^2**	

(Prestressed Concrete Bridge)	New	Area of End Bearing Plate Damage shall be 0.00
	Minor	Area of End Bearing Plate Damage shall be < 50.00
	Moderate	Area of End Bearing Plate Damage shall be < 100.00
	Sever	Area of End Bearing Plate Damage shall be < 200.00
	Failed	Area of End Bearing Plate Damage shall be > 200.00
Pipe-Damage	**%age of Pipe-Damage out of the whole Pipe on the bridge**	
	New	%age of Pipe-Damage shall be 0.00
	Minor	%age of Pipe-Damage shall be < 7.50
	Moderate	%age of Pipe-Damage shall be < 20.00
	Sever	%age of Pipe-Damage shall be < 50.00
	Failed	%age of Pipe-Damage shall be > 60.00
Pipe Blocked	**%age of Pipe Blocked out of the whole on the bridge**	
	New	%age of Pipe Blocked shall be 0.00
	Minor	%age of Pipe Blocked shall be 7.50
	Moderate	%age of Pipe Blocked shall be < 20.00
	Sever	%age of Pipe Blocked shall be < 50.00
	Failed	%age of Pipe Blocked shall be > 60.00
Pipe Inlet-Damage	**%age of Pipe Inlet-Damage out of the whole on the bridge**	
	New	%age of Pipe Inlet-Damage shall be 0.00
	Minor	%age of Pipe Inlet-Damage shall be < 7.50
	Moderate	%age of Pipe Inlet-Damage shall be < 20.00
	Sever	%age of Pipe Inlet-Damage shall be < 50.00
	Failed	%age of Pipe Inlet-Damage shall be > 60.00
Displacement of Concrete Pier, Foundation, Abutment and Wing wall	**Displacement of Concrete Pier, Foundation, Abutment and Wing wall, mm**	
	New	Displacement shall be < 3.30
	Minor	Displacement shall be < 13.75
	Moderate	Displacement shall be < 31.25
	Sever	Displacement shall be < 50.00
	Failed	Displacement shall be > 80.00
Scour at Concrete Pier, Foundation, Abutment and Wing wall	**Pier, Foundation, Abutment and Wing wall Scour, m**	
	New	Scour shall be 0.00
	Minor	Scour shall be < 0.15
	Moderate	Scour shall be < 0.5
	Sever	Scour shall be < 1.00
	Failed	Scour shall be > 1.50
Embankment Depression	**Embankment Depression, mm**	
	New	Embankment Depression shall be 0.00

	Minor	Embankment Depression shall be < 13.75
	Moderate	Embankment Depression shall be < 31.25
	Sever	Embankment Depression shall be < 50.00
	Failed	Embankment Depression shall be > 100.00
Main - Damage for Bearing	**%age of Main - Damage for Bearing out of the whole Bearing on the bridge**	
	New	Main - Damage shall be 0.00
	Minor	Main - Damage shall be < 5.00
	Moderate	Main - Damage shall be < 10.00
	Sever	Main - Damage shall be < 20.00
	Failed	Main - Damage shall be > 50.00
Parts Missing for Bearing	**%age of Parts Missing for Bearing out of the whole Bearing on the bridge**	
	New	Parts Missing for Bearing shall be 0.00
	Minor	Parts Missing for Bearing shall be < 5.00
	Moderate	Parts Missing for Bearing shall be < 10.00
	Sever	Parts Missing for Bearing shall be < 20.00
	Failed	Parts Missing for Bearing shall be > 50.00
Anchor Damage for Bearing	**%age of Anchor Damage for Bearing out of the whole Bearing on the bridge**	
	New	Anchor Damage shall be 0.00
	Minor	Anchor Damage shall be < 5.00
	Moderate	Anchor Damage shall be < 10.00
	Sever	Anchor Damage shall be < 20.00
	Failed	Anchor Damage shall be > 50.00
Bed-Damage for Bearing	**%age of Bed-Damage for Bearing out of the whole Bearing on the bridge**	
	New	Bed-Damage shall be 0.00
	Minor	Bed-Damage shall be < 5.00
	Moderate	Bed-Damage shall be < 10.00
	Sever	Bed-Damage shall be < 20.00
	Failed	Bed-Damage shall be > 50.00
Unusual Movement for Bearing	**%age of Unusual Movement for Bearing out of the whole Bearing on the bridge**	
	New	Unusual Movement shall be 0.00
	Minor	Unusual Movement shall be < 5.00
	Moderate	Unusual Movement shall be < 10.00
	Sever	Unusual Movement shall be < 20.00
	Failed	Unusual Movement shall be > 50.00
Deformation / Deflection of Steel Bridge	**Deformation / Deflection on Steel Bridge, mm**	
	New	Deformation / Deflection shall be 0.00

	Minor	Deformation / Deflection shall be < 1.00
	Moderate	Deformation / Deflection shall be < 2.00
	Sever	Deformation / Deflection shall be < 5.00
	Failed	Deformation / Deflection shall be > 8.00
Fracture /Stee Cracking	**Crack width / Fracture on Steel Bridge, mm**	
	New	Crack width shall be 0.00
	Minor	Crack width shall be < 1.00
	Moderate	Crack width shall be < 1.50
	Sever	Crack width shall be < 3.00
	Failed	Crack width shall be > 7.00
Steel Corrosion	**Area of Corrosion on Steel Bridge, cm^2**	
	New	Area of Corrosion shall be 0.00
	Minor	Area of Corrosion shall be < 400.00
	Moderate	Area of Corrosion shall be < 1000.00
	Sever	Area of Corrosion shall be < 3000.00
	Failed	Area of Corrosion shall be > 5000.00
Wearing of Steel	**Area of Wearing on Steel Bridge, cm^2**	
	New	Area of Wearing shall be < 0.00
	Minor	Area of Wearing shall be < 400.00
	Moderate	Area of Wearing shall be < 1000.00
	Sever	Area of Wearing shall be < 3000.00
	Failed	Area of Wearing shall be > 5000.00
Bolt Missing, Steel Bridge	**Bolt Missing on Steel Bridge, Each**	
	New	Bolt Missing shall be < 0.00
	Minor	Bolt Missing shall be < 1.00
	Moderate	Bolt Missing shall be < 3.00
	Sever	Bolt Missing shall be < 6.00
	Failed	Bolt Missing shall be > 7.00
Paint Peel off, Steel Bridge	**Area of Paint Peel off on Steel Bridge, cm^2**	
	New	Area of Paint Peel off shall be 0.00
	Minor	Area of Paint Peel off shall be < 400.00
	Moderate	Area of Paint Peel off shall be < 1500.00
	Sever	Area of Paint Peel off shall be < 3000.00
	Failed	Area of Paint Peel off shall be > 5000.00

Appendix H

Railway Bridge Damage Weight

Railway Bridge Element Damage Weight

Weighted Average of Bridge Components Defects	Types of Damage		Rank				
			New / No significant importance	Minor	Moderate	Sever / Major	Failed / Critical
			4.610	**9.470**	**15.090**	**26.590**	**44.240**
Super Structure (33.59 %)							
Deck Slab Defects (12.60 %)	Cracking	3.870	0.178	0.366	0.584	1.029	1.712
	Peel off	1.368	0.063	0.130	0.206	0.364	0.605
	Rebar Exposure	2.887	0.133	0.273	0.436	0.768	1.277
	Honeycomb	1.213	0.056	0.115	0.183	0.323	0.537
	Void	1.438	0.066	0.136	0.217	0.382	0.636
	Water Leakage	1.824	0.084	0.173	0.275	0.485	0.807
	Total	**12.600**	**0.581**	**1.193**	**1.901**	**3.350**	**5.574**
Concrete Girder Defects (20.99 %)	Cracking	6.452	0.297	0.611	0.974	1.716	2.854
	Peel off	2.290	0.106	0.217	0.346	0.609	1.013
	Rebar Exposure	4.958	0.229	0.469	0.748	1.318	2.193
	Honeycomb	2.270	0.105	0.215	0.343	0.604	1.004
	Void	2.270	0.105	0.215	0.343	0.604	1.004
	Water Leakage	2.751	0.127	0.260	0.415	0.731	1.217
	Total	**20.990**	**0.968**	**1.988**	**3.167**	**5.581**	**9.286**
Steel Deck Defects (12.85 %)	Deformation	3.374	0.156	0.320	0.509	0.897	1.493
	Cracking	2.903	0.134	0.275	0.438	0.772	1.284
	Corrosion	2.256	0.104	0.214	0.340	0.600	0.998
	Wearing	1.687	0.078	0.160	0.255	0.449	0.746
	Bolt Missing	1.406	0.065	0.133	0.212	0.374	0.622
	Paint Peel off	1.223	0.056	0.116	0.185	0.325	0.541
	Total	**12.850**	**0.592**	**1.217**	**1.939**	**3.417**	**5.685**
Steel Girder Defects (20.74 %)	Deformation	5.446	0.251	0.516	0.822	1.448	2.409
	Cracking	4.685	0.216	0.444	0.707	1.246	2.073
	Corrosion	3.642	0.168	0.345	0.550	0.968	1.611
	Wearing	2.723	0.126	0.258	0.411	0.724	1.205
	Bolt Missing	2.269	0.105	0.215	0.342	0.603	1.004
	Paint Peel off	1.974	0.091	0.187	0.298	0.525	0.873
	Total	**20.740**	**0.956**	**1.964**	**3.130**	**5.515**	**9.175**
Sub Structure (37.79 %)							
Pier & Foundation Defects (15.46%)	Cracking	3.132	0.144	0.297	0.473	0.833	1.386
	Peel off / Stone Deterioration	1.436	0.066	0.136	0.217	0.382	0.635
	Rebar Exposure	2.124	0.098	0.201	0.321	0.565	0.940
	Honeycomb	1.074	0.050	0.102	0.162	0.286	0.475
	Void	0.784	0.036	0.074	0.118	0.208	0.347

	Water Leakage	0.948	0.044	0.090	0.143	0.252	0.419
	Displacement / Bulging	2.381	0.110	0.225	0.359	0.633	1.053
	Scour	3.581	0.165	0.339	0.540	0.952	1.584
	Total	**15.460**	**0.713**	**1.464**	**2.333**	**4.111**	**6.840**
Abutment & Wing wall Defects (14.88 %)	Cracking	3.202	0.148	0.303	0.483	0.851	1.417
	Peel off / Stone Deterioration	1.439	0.066	0.136	0.217	0.383	0.637
	Rebar Exposure	1.921	0.089	0.182	0.290	0.511	0.850
	Honeycomb	1.085	0.050	0.103	0.164	0.288	0.480
	Void	0.908	0.042	0.086	0.137	0.241	0.402
	Water Leakage	1.112	0.051	0.105	0.168	0.296	0.492
	Displacement / Bulging	1.943	0.090	0.184	0.293	0.517	0.860
	Scour	3.269	0.151	0.310	0.493	0.869	1.446
	Total	**14.879**	**0.686**	**1.409**	**2.245**	**3.956**	**6.582**
Embankment Defects (4.28 %)	Depression	1.693	0.078	0.160	0.255	0.450	0.749
	Erosion	2.587	0.119	0.245	0.390	0.688	1.144
	Total	**4.280**	**0.197**	**0.405**	**0.646**	**1.138**	**1.893**
Rip Rap Defects (3.17 %)	Missing	1.073	0.049	0.102	0.162	0.285	0.474
	Erosion	1.126	0.052	0.107	0.170	0.299	0.498
	Displacement	0.971	0.045	0.092	0.147	0.258	0.430
	Total	**3.170**	**0.146**	**0.300**	**0.478**	**0.843**	**1.402**
Ancillaries (9.67 %)							
Bearing Defects (4.56 %)	Main Damage	1.519	0.070	0.144	0.229	0.404	0.672
	Parts Missing	0.611	0.028	0.058	0.092	0.163	0.271
	Anchor Damage	0.679	0.031	0.064	0.102	0.180	0.300
	Bed Damage	0.735	0.034	0.070	0.111	0.195	0.325
	Unusual Movement	1.016	0.047	0.096	0.153	0.270	0.449
	Total	**4.560**	**0.210**	**0.432**	**0.688**	**1.213**	**2.017**
Expansion Joint Defects (1.83 %)	Deformation	0.403	0.019	0.038	0.061	0.107	0.178
	Water Leakage	0.411	0.019	0.039	0.062	0.109	0.182
	Peel off	0.302	0.014	0.029	0.046	0.080	0.134
	Missing	0.364	0.017	0.034	0.055	0.097	0.161
	Noise	0.350	0.016	0.033	0.053	0.093	0.155
	Total	**1.830**	**0.084**	**0.173**	**0.276**	**0.487**	**0.810**
Kerb & Railing Defects (1.63 %)	Cracking	0.318	0.015	0.030	0.048	0.084	0.141
	Peel off	0.212	0.010	0.020	0.032	0.056	0.094
	Rebar Exposure	0.273	0.013	0.026	0.041	0.073	0.121
	Deformation	0.318	0.015	0.030	0.048	0.084	0.141
	Corrosion	0.212	0.010	0.020	0.032	0.056	0.094
	Missing	0.298	0.014	0.028	0.045	0.079	0.132
	Total	**1.630**	**0.075**	**0.154**	**0.246**	**0.433**	**0.721**
Bridge Drainage	Pipe Damage	0.631	0.029	0.060	0.095	0.168	0.279

Defects (1.66 %)	Blocked	0.593	0.027	0.056	0.090	0.158	0.262
	Inlet Damage	0.436	0.020	0.041	0.066	0.116	0.193
	Total	**1.660**	**0.077**	**0.157**	**0.250**	**0.441**	**0.734**
Railway Track Structure over the Bridge (18.95 %)							
Railway Track Structure Element Defects (18.95%)	Defects on Rail	6.759	0.312	0.640	1.020	1.797	2.990
	Defects on Rail Fasteners	2.856	0.132	0.270	0.431	0.759	1.263
	Defects on Sleeper	3.832	0.177	0.363	0.578	1.019	1.695
	Defects on Ballast	3.521	0.162	0.333	0.531	0.936	1.558
	Defects on Ballast Retainers	1.982	0.091	0.188	0.299	0.527	0.877
	Total	**18.950**	**0.874**	**1.795**	**2.860**	**5.039**	**8.383**

Appendix I

Sample Photo of Railway Bridge Defects

Corrosion of rail along Aama - Awash section [23]

Rail at curve section, showing longitudinal irregularity and lack of guard rail along Aama - Awash section. [23]

Uneven expansion Joints of rails along Aama - Awash section [23]

Unfilled ballast under the sleeper along Aama - Awash section [23]

Lack of uniform width of ballast section; too narrow and too wide respectively Adama-Awash [23]

Oversized and Poor quality ballast respective along Adama-Awash Section [23]

Dust and silt on railway track. [23]

Unfilled ballast under the sleeper along Adama-Awash Section [23]

Loose and missing bolts around Metehara and Olenchiti [23]

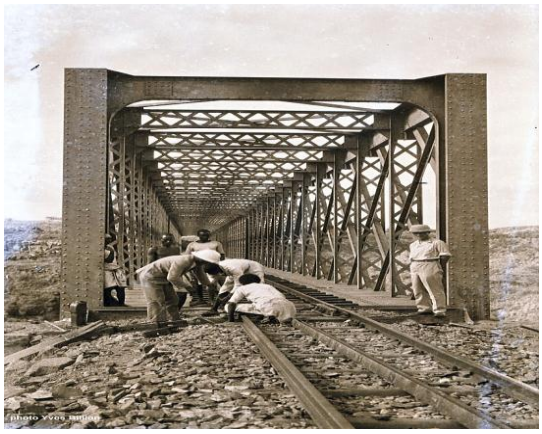
Poor Culvert design at location 137 DK, around Olenchiti sleeper factory [23]

Water Leakage through Expansion Joint and Drainage Pipe in Good Condition, AALRT around Legehar

Bridge around Olenchity repeatedly hitted by oversize vehicles, ERC

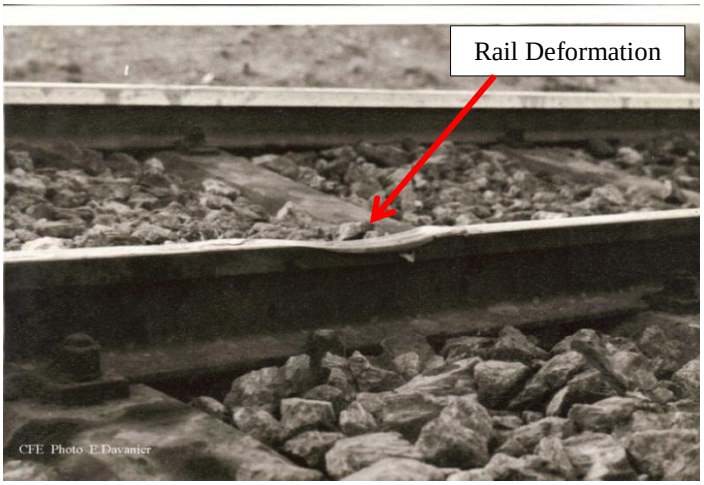
Water Way Scour bridge located around Awash 2008, Ethio-Djibouti Railway Line [22]

Level & Gauge Checking around Metehara (Beseka Lake) during the rehabilitation of Ethio-Djibouti Railway Line [22]

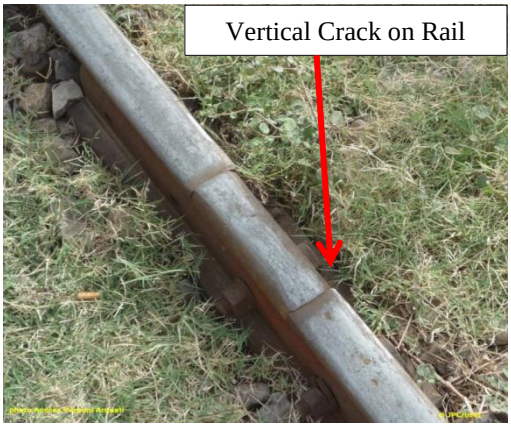


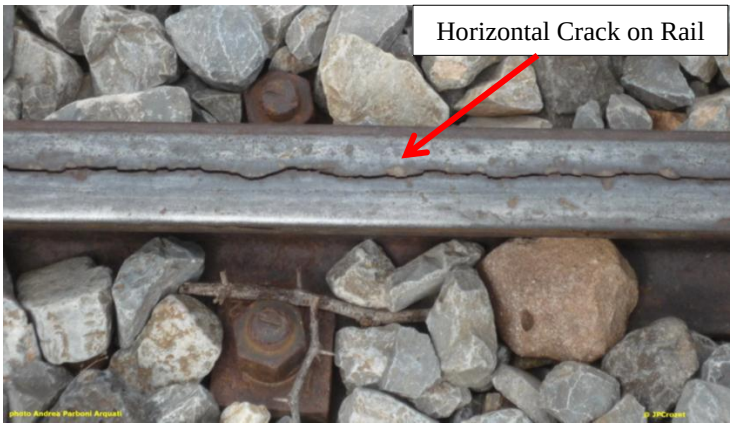
Truck Inspection on Aouache Bridge 1930 and Track Inspection 1956 Ethio-Djibouti Railway Line [22]

Corrosion of Rail, Ethio-Djibouti Railway Line [22]



Deformation of rail, Ethio-Djibouti Railway Line 1964 [22]

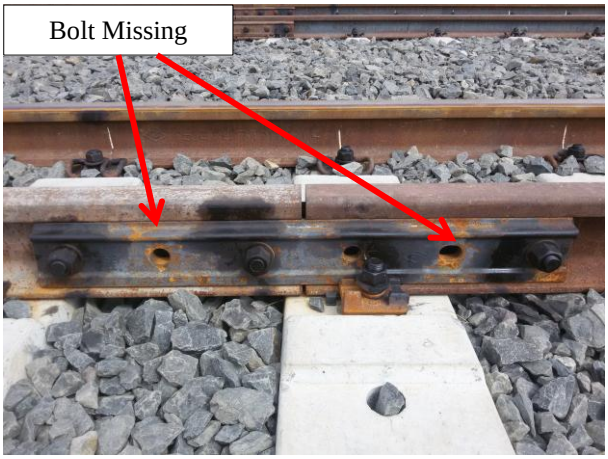




Vertical and Horizontal Crack on Rail, Ethio-Djibouti Railway Line 1964 [22]

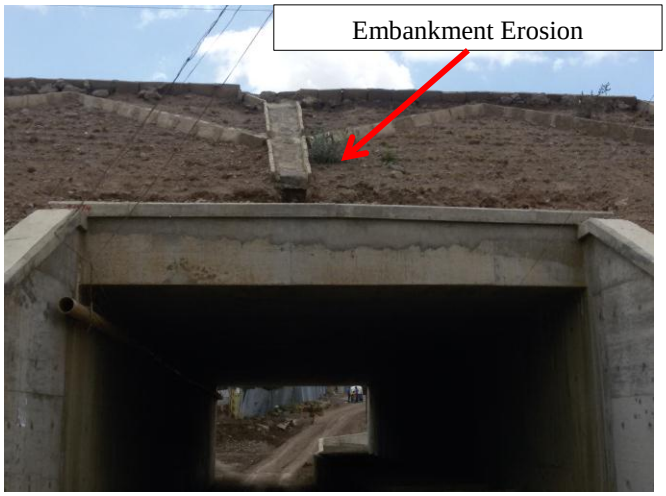
Damaged Rail at Weld, Ethio-Djibouti Railway Line 1964 [22]

Too Narrow and Too Wide Rail Expansion Joints, Around Alemgena ERC



Bolt Missing, Around Alemgena ERC

Water way Scour and Siltation on Bridge around Alemgena, ERC



Embankment Erosion on Bridge around Alemgena, ERC

Slightly Blocked Drainage Pipe on bridge around Alemgena, ERC