Failure Analysis

Diagnosis Report

Local Government Engineering Department

Local Government Division

Ministry of Local Government, Rural Development, & Cooperatives

Government of the People's Republic of Bangladesh

October 2022

Local Government Engineering Department

Failure Analysis

Diagnosis Report

October 2022

National Resilience Programme

The Failure Analysis Diagnosis Report sets the ground for a series of technical documents on Failure Analysis for the Local Government Engineering Department (LGED). The report has been prepared through a collaborative and consultative process between LGED and the United Nations Office for Project Services (UNOPS). This report aims to identify hazards and risk factors from Governance/Legal Framework to Operation/Maintenance, and over intermediate stages such as Planning, Detail Design and Construction, in order to support the Local Government Engineering Department (LGED) through a Forensic Engineering Approach to define the principal investment areas and technical training required to improve the safety and resilience of transport infrastructure (rural roads and bridges) in Bangladesh.

This report is one of the deliverables of LGED and United Nations Office for Project Services (UNOPS) Sub-project, under the Joint National Resilience Programme (NRP) for the Government of Bangladesh. UNOPS provided technical assistance and advisory support to LGED in the implementation of the Sub-project.

The NRP is a joint programme of UNOPS, UN Women, and UNDP in partnership with the Local Government Engineering Department, Department of Disaster Management, Department of Women Affairs and Programming Division of the Government of Bangladesh (GOB). The Programme is funded by the governments of the UK, Sweden, and Bangladesh.

UKaid from the British people

Sweden Sverige

UN WOMEN United Nations Entity for Gender Equality and the Empowerment of Women

UNOPS

UNDP

Preface

As part of the National Resilience Programme's Failure Analysis workstream, the Local Government Engineering Department (LGED) and the United Nations Office for Project Services (UNOPS) collaborated to develop a series of technical documents, including:

Diagnostic Report: This report aims to identify hazards and risk factors throughout the lifecycle of transport infrastructure (roads and bridges) in Bangladesh. It covers areas such as Governance, Legal Framework, Planning, Detail Design, Construction, Operation, and Maintenance, and utilizes a Forensic Engineering Approach.

Failure Analysis Framework: This report provides support documentation and a toolkit for assessing both shallow and deep causes of structural failures in rural infrastructure roads and bridges. It also identifies the triggering effects and the most likely origin of the failures.

Guidance Material for Road and Bridge Pathologies: It offers guidance for analyzing 15 specific pathologies related to rural infrastructure, including 10 for bridges, 3 for pavement, and 2 for embankment.

ToolKit and Toolkit User Manual: This document provides a toolkit along with a user manual. The toolkit supports the assessment of structural failures in roads and bridges, while the user manual offers guidance on how to effectively utilize the toolkit.

This specific document pertains to the Diagnostic Report.

EXECUTIVE SUMMARY

Context of Roads and Bridge Failures

The Local Government Engineering Department (LGED) plays a key role in fulfilling the Vision 2021 goals of the Government of Bangladesh by developing and maintaining the rural road connectivity (**353,140 km of rural roads and 1,245,233 m of bridge/culverts, excluding U-drain, lies on the rural road network)**.

LGED and Local Government Institutes (LGIs) have under their jurisdiction around 353,140 km of roads, of which 236,913 km (67%) are earthen roads. The remaining **33% are paved roads** (**78% with flexible pavement, 3.4% with rigid pavement and 18.6% is brick pavement**).

The 36% of the total **road network** under the jurisdiction of LGED is considered to be in **poor or bad conditions**. Percentage wise, **Union Road** presents the highest percentage 11,353km / 41,828km = 27%. The condition status of bridges and culverts based on the 2018 survey done by LGED represents that 4.7% of the structures have major elemental damage with 5.1 % minor elemental damage.

Preliminary independent assessment of the **most probable roads and bridges failures modes (pathologies)** on the basis of site picture analysis is consistent with the observation and major failure mode definition as defined by LEDG and these are:

- Road Failure Modes: a) Embankment slope failure - Static Stability -; b) Scour slope failure; c) Pothole; d) Pavement wash-out (inner and pavement edge);

- Bridge failure modes: a) Structural static system (mechanisms); b) Concrete spalling; c) Concrete cracks; d) Settlement/lining of structure; e) Foundation scour; and f) Lockdown of mechanical devices:

It is recommended to amend current work on Strategic Asset Management Plan and corresponding **Asset Management Plan** with an additional level "**Level 6 / Observations / Weakness sign (WS)**".

Governance and Legal Framework

There is a structured regulatory system in Bangladesh, highly centralized at the Government level.

It would seem that the Design Regulatory Framework is "compendium" of norms, codes, regulations, manuals… (**essentially driven by the AASHTO Load and Resistance Factor Design (LRFD) Code and local regulatory technical documents**) with inserts of the "Bangladesh National Building Code" (BNBC) and **"**Building Code Requirements for Structural Concrete (ACI 318-14)" which coherence and cross references shall be properly revisited.

The implementation of the AASHTO LRFD Bridge Design Specification is expected shortly, and is strongly suggested as an essential step a) to enhance the uniformity of codes/norms to be used and b) to provide a coherent and consistent level of safety, serviceability, constructability, bridge aesthetics and overall economic life of rural bridges, at the same time as c) a wider access to the Roads and Bridges Design Norms are granted.

The LGED follows the 'Road Design Standard' introduced by the Planning Commission of Bangladesh in 2004. Unexpected increase in traffic volume and unusual rapid changes in rural traffic patterns are identified as the main reasons behind such failures. Recently, LGED has revised their 'Road Design Standard' which is under process for approval by the Planning Commission, and therefore yet to be implemented.

Hazard Maps for Bangladesh at State, Regional and Provincial Levels are yet to be published for comment, and to be adopted by the Planning Commission.

Implication of climate change related actions/design recommendations in road and bridge design is yet to be implemented consistently across the different projects and "normalized" by the planning commission.

Stakeholders

Stakeholders are defined between **state agencies** (ministerial and local government levels) and **private entities** (engineering consultant firms and contractors).

LGED is a highly structured Local Government entity taking several roles within the infrastructure design life covering planning, design, quality assurance/quality control, operation, inspection and maintenance, finance, …. which requires significant communication and coordination effort among different departments/units. Under this project organization structure, the project risks and corresponding mitigation measures are not optimally distributed across the different potential market stakeholders.

Planning: At the Planning stage, **Prefeasibility Studies** are essentially driven by a) **economical aspects** under the "Guideline for the preparation of the pre-feasibility study of the projects in section 15 of Part B of Part 1 (March 2014)", and b) by **political strategies** laid out previously during the government election period. **Technical risk assessment** of the different projects does not seem to be undertaken at this early stage of planning and to enforce the **implementation of the DIA (Disaster Impact Assessment)**.

Each Natural Public Agency is developing their own hazard map, including **climate change considerations**, but these are yet to be published for comments.

The LGED's challenge is to balance growing needs with limited resources in a changing environment. Beside this, there still exists an Inadequate flow of funding.

"Opportunities" and "Recommendations" are listed in the section 4: planning of the present Desk Study Report.

Design: While the **Design process** includes the main parts of the industry´s good practices in the definition of Engineering Technical Documentation for Construction Tendering Process (public procurement) an example of such Road and Bridge design could not have been obtained for further inside in the level of detailing of the different technical documents and their readiness for construction works.

The definition of **resilient infrastructure design and post-disaster risk assessment** as part of a **sustainable development** strategy shall be the backbone of the road and bridge design with circular "lesson learnt" and continuous learning to "**Build Back Better**" (BBB) infrastructure.

Special attention should be driven in the definition of the **three (3) major hazard design loads (river flooding, wind, and temperature)** and the consistent implementation of technical feasibility studies before the start of the Design stage. This would clearly allow to **mitigate upfront some of the design risks** and to implement a design that is **robust and resilient** vis-à-vis those risks that could not be eliminated, but certainly highly mitigated during the Design stage.

As part of the design process, **strengthening the design review and international review of LGED's customized Road Design Standards** (manuals and drawings) shall be evaluated, in conjunction with additional requirements in the definition of **construction sequence documentation** from the designer and **working drawings** from the contractor for designer´s review and approval.

LGED has developed an internal career-path to excel in design excellence. Conversely to Building Designer (compliance with a minimum of 7 years proven practice and a pre-established training curricula), **no chartership certifications and continuous learning accreditation** are required for a **road or bridge designers**. Therefore, it is suggested that a continuous learning path at all engineering category levels (career path at LGED) with national and/or international certification programmes be implemented.

The **Superintending Engineer** (designer) is the chief official for approval of designs and ensures a) quality control, b) safety, c) economical project viability, d) project sustainability and durability strategy, e) respond to policy matters, f) defines construction stages and g) defines/clarifies ethical aspects necessary to attain and maintain the highest level of quality in infrastructure design process.

The Executive Engineer is legally responsible for the design of roads and bridges.

"Opportunities" and "Recommendations" are listed in the section 5: Design of the present Desk Study Report.

Procurement and Construction: Public Procurement is regulated by the Public Procurement Law, 2006 (PPA, 2006), Public Procurement Rules, 2008 (PPR, 2008) and Electronic Government Procurement Guidelines, 2011. Public Procurement allows for several procurement methods, which largely depends on the capacity of the local/national market. The most commonly used procurement method within LGED is One Stage Two Envelope Method (OSTEM) Procurement system.

While the **Procurement process** is clear and well defined**, its implementation within LGED varies from project to project**, with significant deviation in roads and minor deviations in bridges.

There is an acute scarcity of high-quality natural materials for use as aggregates in pavements and cement concrete, throughout Bangladesh. Alternative solutions are implemented with a direct impact into the infrastructure performance and design life of its key components. As a common design change situation, mitigation measures should be implemented in the Planning and Design stages. Import of high-quality material can only be done on large infrastructure projects (>100'000 million BDT).

The construction industry in **Bangladesh exerts a high demand for bitumen**. The only bitumen producing company in Bangladesh (Eastern Refinery) is unable to cope with the demand and import is still limited to bitumen from India, Iran and Singapore though the quality varies widely but within the acceptable limit.

While there is no iron available in Bangladesh to produce steel, a number of steel mills have been established in the country by Bangladeshi entrepreneurs**. These mills produce rebars from scrap iron**, which leads to uneven chemical composition across the different rebar batches resulting in **uneven mechanical properties for design basis** (uneven capacity across the same structural component).

Neither pre-tensioning nor post-tensioning high tension wire is produced in Bangladesh and technology requires foreign expertise.

“Opportunities” and “Recommendations” are listed in the section 6: procurement and construction of the present Desk Study Report.

Inspection and Maintenance: Despite the different attempts, the allocation of financial resources to maintain the built infrastructures remained far below the needs. Lack of financial/budgetary mechanisms leading to a lack of financial support to a) Operation and Maintenance personnel, and b) infrastructure lifetime investment (Infrastructure Asset Value), resulting in a premature “aging” infrastructure. The **50% of the LGED paved network have exceeded the maximum design life (+10years)**, resulting in accelerated deterioration rate and LGED does not have any formal mechanism to monitor the KPIs/Performance Service Level to evaluate their investment in maintenance work (maintenance and repair works). **The routine maintenance is mostly done as a “reactive maintenance” instead of “preventive maintenance”**.

Nationwide programs and guidelines are developed to account for the whole cycle of the maintenance activities including survey, planning, preparation, implementation and monitoring & evaluation. It also provides the directives in regards to administrative, technical and financial aspects. **An Asset Management Policy has already been developed under the National Resilience Programme**.

“Opportunities” and “Recommendations” are listed in the section: 7 Operation and Maintenance of the present Desk Study Report.

TABLE OF CONTENTS

List of Acronyms

AASHTO	American Association of State Highway and Transportation Officials
ACI	American Concrete Institute
ADB	Asian Development Bank
AMP	Asset Management Plan
ASTM	American Society for Testing and Materials
BACI	Bangladesh Association of Construction Industry
BBA	Bangladesh Bridge Authority
BCCSAP	Bangladesh Climate Change Strategy and Action Plan
BIWTA	Bangladesh Inland Water Transport Authority
BM	Benchmark
BNBC	Bangladesh National Building Code
BUET	Bangladesh University of Engineering and Technology
BWDA	Bangladesh Water Development Authority
C&AG	Comptroller and Auditor General
C3ER	Centre for Climate Change and Environmental Research
CPTU	Central Procurement Training Unit
CRIMP	Climate Resilient Infrastructure Mainstreaming Project
DTM	Digital Terrain Model
ECNEC	Executive Committee of the National Economic Council
e-GP	e-Government procurement
EIA	Environmental Impact Assessment
FFWC	Flood Forecasting and Warning Centre
GA	General Arrangement
GCF	Green Climate Fund
GDP	Gross Domestic Product
GIS	Geographic Information System
GoB	Government of Bangladesh
GPS	Global Positioning System
ICCCAD	International Centre for Climate Change and Development
IEE	Initial Environmental Examination
IMED	Implementation Monitoring and Evaluation Division
IRI	International Roughness Index
IWFM	Institute of Water and Flood Management
JICA	Japan International Cooperation Agency
LCS	Labor Contracting Society

LGD	Local government Division
LGED	Local Government Engineering Department
LGI	Local Government Institutes
LRFD	Load and Resistance Factor Design
MDB	Multilateral Development Bank
MDG	Millennium Development Goal
MIS	Management Information System
MMT	Mobile Maintenance Team
MoF	Ministry of Finance
MTBF	Mid Term Budgetary Framework
PDPP	Preliminary Development Project Proposal
PE	Procuring Entity
PM&E	Project Monitoring and Evaluation Unit
PMU	Project Management Unit
QC	Quality Control
RHD	Roads and Highways Department
RMRSU	Road Maintenance and Road Safety Unit
RSDMS	Road and Structure Database Management System
SAMP	Strategic Asset Management Plan
SDG	Sustainable Development Goal
TAPP	Technical Assistance Project Proposal
TEC	Tender Evaluation Committee
ToC	Tender Opening Committee
UNOPS	United Nations Office for Project Services
WARPO	Water Resources Planning Organisation
WB	World Bank

1. INTRODUCTION

Aim and Objectives

The aim of this work is to develop an understanding of the vulnerability of existing rural infrastructure (roads and bridges) in Bangladesh in the face of natural hazards, effects of climate change, as well as the risk factors (both acute shocks and chronic stresses) induced by multiple sources and present across the infrastructure construction cycle.

This report aims to identify these hazards and risk factors from Governance/Legal Framework to Operation/Maintenance, and over intermediate design stages such as Planning, Detail Design and Construction, in order to support on the following stage the Local Government Engineering Department (LGED) through a Forensic Engineering Approach to define the principal investment areas and technical training required to improve the safety and resilience of transport infrastructure (roads and bridges) in Bangladesh.

The objectives of this report are:

a) To undertake a rapid national-level diagnosis (desk study) to get an informed understanding of the vulnerability of rural road and bridge infrastructure network in Bangladesh and contributing factors of risk;

b) To understand the range of hazards and drivers of risk that may compromise the planning, design, reconstruction, repair and retrofitting, and operation of rural transport (bridges and roads) infrastructure in Bangladesh;

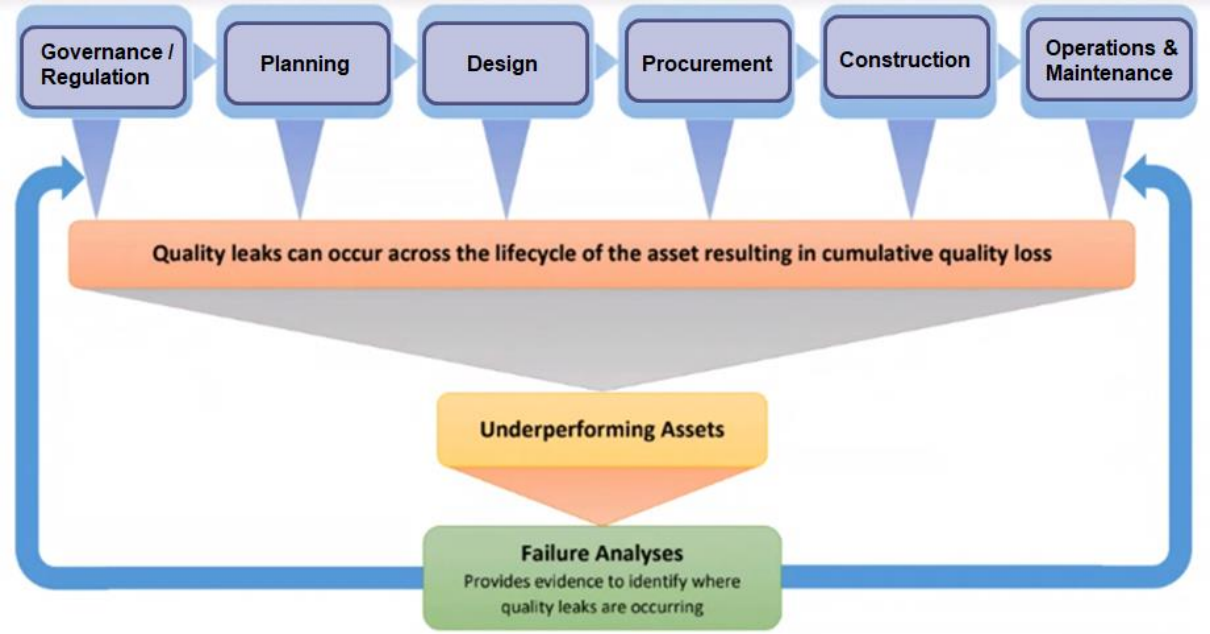
c) To increase the understanding of resilient infrastructure in Bangladesh, by establishing a baseline of the rural transport infrastructure. This will include understanding the existing rural road infrastructure system, most common bridge and road pavement typologies, infrastructure distribution as well as the government's plans to expand and/or consolidate its infrastructure;

d) To understand the institutional and policy environment and regulatory framework within which rural transport (roads, bridges) infrastructure is planned, designed, constructed, operated, maintained, repaired and retrofitted in Bangladesh and identify the main challenges the government faces to ensure sustainability and resilience of the growing investments in rural transport infrastructure;

e) To identify advances and gaps in resilient infrastructure practices regarding planning, design, construction, maintenance, repair and retrofitting and provide an overview of the capacity and capability of the local engineering and construction industry;

f) To understand the financial environment in which infrastructure are planned, designed, constructed, operated and maintained;

g) Make recommendations to support the LGED advance infrastructure resiliency by highlighting and prioritizing key activities and investment opportunities throughout the implementation process (planning, design, construction and operation and maintenance) of rural transport infrastructure, and policy reforms and steps to ensure that new infrastructure is safe and resilient;



This diagnosis report (desk study) is structured so that the obtained information and resulted conclusions can be implemented quickly and efficiently. As such each chapter of this report is structured identically with a first section related to "**Key Findings**" and "Weaknesses" (introduced by the adverb "**However**") and close-out with a section on "**Opportunities**" and "**Recommendations**" (refer to grey boxes). "Opportunities" tries to provide the main axes of future development/strategy while "Recommendations" brings these axes to a lower level, similar to a specific project.

Following this diagnosis report (desk study), UNOPS along with Arup (a global engineering firm) will develop a Failure Analysis methodology to help LGED to identify the cause(s) and potential origin of the failure. The format of this methodology will be based on a Failure Analysis (Forensic Engineering) Approach with an attempt to develop a proprietary Failure Analysis work-flow which will later be developed into a course/workshop, and training material, in due time.

2. CONTEXTS OF ROADS AND BRIDGES FAILURES

Aim and Objectives

This section´s objective is to provide a first glance of the **most common road and bridge failure within the LGED infrastructure** assets in Bangladesh. Failure shall be understood as either a) partial or b) complete infrastructure failure inducing the lack of infrastructure serviceability or c) recurrent infrastructure pathology with places in the society.

Key findings

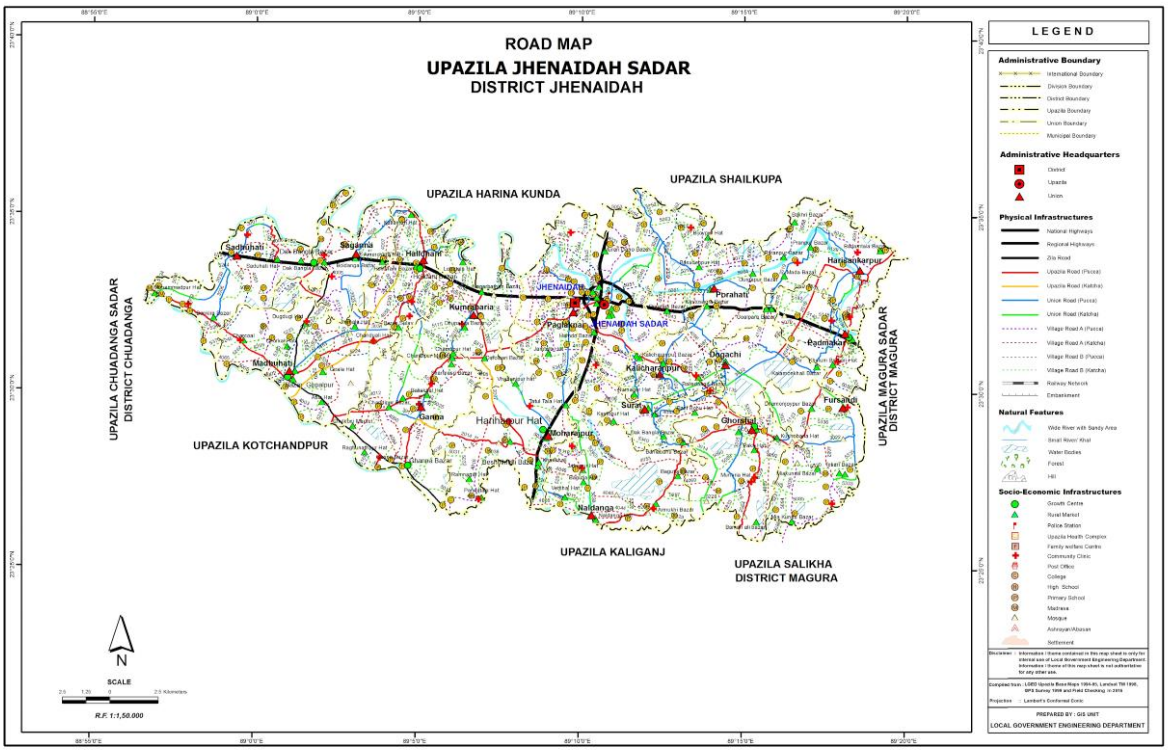
- LGED plays a key role in fulfilling the Vision 2021 goals of Government of Bangladesh by developing and maintaining the rural road connectivity (**353,140 km of rural roads and 1,245,233 m of bridge/culverts (excluding U-drain) lies on the rural road network)**;
- LGED and Local Government Institutes (LGIs) have under their jurisdiction around 353,332 km of roads, of which 236,913 km (67%) are earthen roads. The remaining **33% are paved roads** (**78% with flexible pavement and 3.4% with rigid pavement**);
- Preliminary independent assessment of the **most probables roads and bridges failures modes (pathologies)** on the basis of site picture analysis is consistent with the observation and major failure mode definition as defined by LGED;

Context

The transport system of Bangladesh consists of roads, railways, inland waterways, two seaports, maritime shipping, and civil aviation, catering to both domestic and international traffic. The country has about 406,000 kilometers (km) of roads, including about **22,000 km of major roads**; **4,250 km of urban roads**; 2,877 route-km of railways; 24,000 km of perennial waterways and the ports of Mongla and Chittagong; and three international airports (Dhaka, Chittagong, and Sylhet) and eight domestic airports. The distribution of land and water transport network is shown below:

Roles and Responsibilities	Type of Transport Network	Length in km	Total Network in km
Roads and Highways Department (RHD)	National Highways	3,906.03	
	Regional Highways	4,766.91	
	Zilla Road	13,423.36	
	Major Road Network		22,096.30
Local Government Engineering Department (LGED)	Upazila Roads (Red and Orange Color)	37,597.67	
	Union Roads (Blue and Green Color)	41,862.59	

Roles and Responsibilities	Type of Transport Network	Length in km	Total Network in km
	Village Roads (Type A) - (Dashed Purple and Pink Color)	128,098.82	
	Village Roads (Type B) - (Dashed Blue and Green Color)	145,580.94	
	Rural Road Network		353,140.02
Bangladesh Railways (BR)	Railway Track		2,877.00
City Corporation/ Municipalities	Urban Road		4,245.00
Bangladesh Inland Water Transport Authority (BIWTA)	Inland Waterways		24,000.00



Local Government Engineering Department (LGED) – a central government department, under the Ministry of Local Government, Rural Development & Cooperatives, is one of the largest public sector technical and development organizations in Bangladesh. It plays a key role in fulfilling the Vision 2021 goals of Government of Bangladesh (GoB) by **developing and maintaining the rural road connectivity [353,140 km of rural roads and 1,245,233 m of bridge/culverts (excluding U-drain)** lies on the rural road network] to rural market also rural Growth Center (GCs) with health facilities, higher education centers, and market centers through Zila/Regional roads. The LGED is also responsible for the development and

maintenance of other civil infrastructure that has directly strengthened the rural economy and contributed to the national GDP growth of Bangladesh.

LGED and Local Government Institutes (LGIs) have under their jurisdiction around 353,140 km of roads, of which 236,913 km (67%) are earthen, and therefore the remaining 33% are paved roads. Paved roads are further broken down in 78% with flexible pavement and 3.4% with rigid pavement, while the rest 18.6% is developed with brick i.e semi paved.

LGED collects both International Roughness Index (IRI) and the detailed condition data to quantify how the paved network is performing. However, while IRI data is used to identify the road performance level, analysis of the available LGED's Road and Structure Database Management System version 8 (RSDMS-VIII) data indicates that there is a significant number of roads/segments, IRI survey is not carried out every year. While discussing with the Maintenance Unit of LGED, it was noted that due to survey related funding constraints, typically IRI is collected for those pavements that are perceived as 'bad road' by the LGED Field Engineers. However, according to the latest survey carried out in 2018, 34% of paved roads are in good condition and 29% in fair condition and rest are in poor to bad condition. Road type wise pavement condition is presented below:

LGED rates road surface condition (roughness) based on the International Roughness Index (IRI), as per table below:

Condition Rating	IRI Range
Good	IRI <=6
Fair	>6 IRI <=8
Poor	>8 IRI<=10
Bad	IRI >10

Road Type	Total Length (km)	Paved Road Length (km)	Good Road Length (km)	Fair Road Length (km)	Poor Road Length (km)	Bad Road Length (km)
Upazila Road	37,254	33,352	12,173	9,872	6,003	5,303
Union Road	41,828	28,171	10,057	6,761	6,198	5,155
Village Road	274,250	54,896	17,512	17,567	12,626	7,191
Total	353,332	116,419	39,742	34,200	24,827	17,649
% w.r.t Total Paved Length			34%	29%	21%	15%

As per the above table, 36% of the total road network under the jurisdiction of LGED are considered to be in poor or bad conditions. Percentage wise, **Union Road** presents the highest percentage 11,353km / 41,828km = 27%;

There are approximately 1,290,796 m of bridges and culverts with an additional 689,149 m remaining to be developed. The stock of the bridge and culverts comprises the following type of structure.

	Upazila Road		Union Road		Village Road (A & B)	
Structure Type	**Nos.**	**Total Length (m)**	**Nos.**	**Total Length (m)**	**Nos.**	**Total Length (m)**
Arch Masonry	151	642.18	184	591.75	290	791.12
Bailey Bridge	142	5556.25	58	1990.04	84	1468.34
Bailey with Steel Deck	87	3507.57	34	1816.90	20	647.95
Box Culvert	25466	108711.34	19282	82587.68	29780	114756.38
Hydraulic Structure	751	3757.06	646	2881.40	752	3590.81
Iron Bridge	457	10140.26	1308	25836.91	5270	84697.81
Light Traffic Bridge	375	8982.29	1100	25747.10	4791	91958.66
PC Girder Bridge	185	31079.50	100	10332.99	135	4913.03
Pipe Culvert	8103	9499.70	10413	12549.09	34243	35376.08
RCC Girder Bridge	6315	187991.45	4502	105363.53	7294	121072.99
Slab Culvert	6331	23208.64	8332	27296.15	26215	70029.85
Steel Beam & RCC Slab	32	921.69	36	689.60	61	1126.95
Truss with RCC Slab	25	684.85	39	982.15	45	760.66
Truss with Steel Deck	125	5610.96	57	2838.17	77	2409.64
U-Drain	13219	16936.33	15822	20437.32	29821	41084.40
Wooden Bridge	52	788.80	78	1628.00	488	7419.72

The frequency of structure surveys is generally related to the physical condition of the structure. Typical frequencies of the different levels of structure surveys are present below.

Bridge Typologies

According to the 2018 RSDMS database, 47% of the LGED network structure length is acquired by the bridges longer than 20 m. In case of longer structures, The GoB gazette published February, 2015 provides **LGED with 100% ownership of the all bridge structure (length up to 1500 m) within their jurisdiction of Rural Road Network as well as to build the bridge up to 1500 m**.

Though the present version of RSDMS stores data of 17 types of structures. **There are 8 types of bridges commonly built in the country**. On the basis of their basic functional and design characteristics, the definitions and descriptions of each structure type is presented below:

Structure Type	Description	
Box Culvert (Monolithically connected Walls and Slabs)	Box Culvert is a rectangular-shaped, reinforced concrete drainage structure either cast in situ or precast in sections. They are most commonly used for water courses.	
U-Drain	U-drains are very small length structures provided for passing water. There is no wing wall in the structure. Only two vertical walls (either brick masonry or reinforced cement concrete) are provided which work as abutments and a top slab is provided over it.	

Structure Type	Description	
Pipe Culvert	Pipe culvert is a buried pipe for carrying a watercourse below ground level. It can be made of polyethylene pipe, concrete and metal pipe. Its main purpose is to provide cross drainage facilities in particularly low priority roads.	
Slab Culvert	Culvert is a structure constructed over running water or physical obstruction. The main purpose of constructing culvert structure is to provide passage over the obstruction. Slab culvert, a type of culvert, could be three-sided or simply a deck slab. It is embedded in the soil on both sides.	
RCC Girder Bridge	A girder bridge, in general, is a bridge that uses girders as the means of supporting the deck. The girders themselves are the primary support for the deck, and are responsible for transferring the load down to the foundation. The whole structure is usually made of concrete.	
Iron Bridge	An iron bridge is a bridge that uses EI rail, MS angle and timber as its principal structural material. The piers are constructed with EI rail. Wooden planks are used for deck slabs and MS angles are used for railing and rail post. It is a temporary structure for passing light traffic vehicles (pedestrian, bicycle, motorcycle and three wheelers).	

Structure Type	Description	
Light Traffic Bridge	Light Traffic Bridge is one kind of RCC Girder Bridge with very narrow width. These types of bridges were installed in rural roads where connectivity was required but there was very less possibility of vehicular movement. These bridges were made within a limited cost and thus these bridges are also called low-cost bridges.	
Hydraulic Structure	Sluice Gate typed structures are commonly constructed to control the water flow in a defined channel. Typical construction materials are cast iron for the frame, gate, and guides. Wedges, thrust nut, lift nut, and couplings are bronze castings. Seat facings are extruded bronze. Stems and fasteners are stainless steel.	
Arch Masonry	An arch bridge is a bridge with abutments at each end shaped as a curved arch. Arch bridges work by transferring the weight of the bridge and its loads partially into a horizontal thrust restrained by the abutments at either side. Stone, brick and other such materials are strong in compression and somewhat so in shear, but cannot resist much force in tension.	
Wooden Bridge	A timber bridge or wooden bridge is a bridge that uses timber or wood as its principal structural material. It is a bridge with wooden spans and supports. Timber bridges may also have concrete supports.	

Structure Type	Description	
PC Girder Bridge	It is similar to the RCC girder bridge with a contrast that the girders are constructed with prestressed (compressed) concrete is a form of concrete used in construction. This compression is produced by the tensioning of high-strength "tendons" located within or adjacent to the concrete and is done to improve the performance of the concrete in service.	
Bailey Bridge (with/without) Steel Deck	The Bailey bridge is a type of portable, pre-fabricated, truss bridge. It was developed by the British during World War II for military use and saw extensive use by British, Canadian and the American military engineering units.	
Truss with Steel Deck / Truss with RCC Slab	A truss bridge is a bridge whose load-bearing superstructure is composed of a truss, a structure of connected elements usually forming triangular units. The connected elements (typically straight) may be stressed from tension, compression, or sometimes both in response to dynamic load.	
Steel Beam & RCC Slab	It is a composite bridge consisting of steel girders and concrete deck. It is typically used where longer horizontal clearance is required to reduce deflection in and size of the girder. This is done using 'shear connectors' fixed to the steel beams and then embedded in the concrete.	

There is no specific preference from stakeholders in regards to bridge type selection. The selection of bridge types depends on technical considerations, local site condition, availability of materials, and skill of the construction market. Mostly, in the coastal area, steel bridge gets

preference from chlorination point of view. But, in rural roads, majority bridges are constructed with concrete.

The designer always prefers to choose short spanned (< 50m) bridges as it is easier to design. About 10 years back, the government had instructed to adhere to Bangladesh Inland Water Transport Authority (BIWTA)'s navigational criteria. Before that, BIWTA's navigational (horizontal and vertical clearance) criteria in selecting the bridge-span was not followed in most of the cases.

LGED has started to construct precast segmental box girder bridges on river type 1 and 2 where the minimum requirement of horizontal navigation is 76.22 meter.

Classification of waterways	Minimum vertical clearance (meter)	Minimum horizontal clearance (meter)
Class - I	18.3	76.22
Class - II	12.2	76.22
Class - III	7.62	30.48
Class - IV	5	20

Roads Typical cross section

Since 2005, the following design standards (Table-A & Table-B) have been followed for construction of rural roads. Table-C represents the pavement standards

Table-A: Geometric dimension rural roads

Road Class	Design Type	Carriageway (m)/(ft)	Hard Shoulder (m)/(ft)	Verge (m)/(ft)	Crest Width (m)/(ft)
Union Road	8	3.0 / 10	0.0 / 0	1.25 / 4	5.5 /18
	7	3.7 / 12	0.0 / 0	0.90 / 3	5.5 / 18
Upazila Road	7	3.7 / 12	0.0 / 0	0.90 / 3	5.5 / 18
	6	3.7 / 12	0.0 / 0	1.8 / 6	7.3 / 24
	5	3.7 / 12	0.9 / 3	0.9 / 3	7.3 / 24
Zila Road	6	3.7 / 12	0.0 / 0	1.8 / 6	7.3 / 24
	4*	5.5 / 18	0.0 / 0	2.15 / 7	9.8 / 32
	3	5.5/18	1.2/4	0.95/3	9.8/32

*In case of land acquisition problem and resource constraint, crest width of 7.3 metre/24 feet may be allowed in special cases.

Table-B: Design type selection criteria

Design Type	Daily Commercial Vehicles (CVD)
8	Up to 50
7	51-100
6	101-200
5	201-300
4	301-400

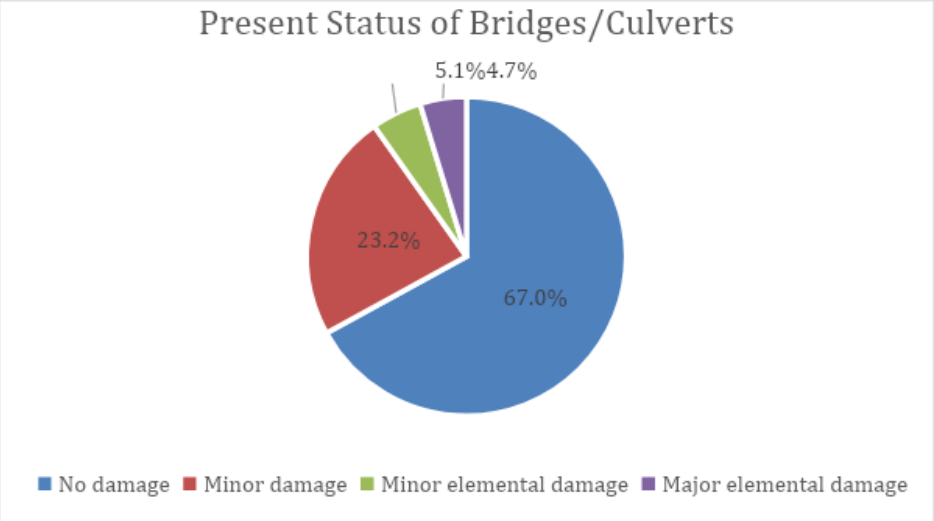
Table-C: LGED's Typical Pavement Cross Section

	Design Type									
Pavement Layer Thicness (mm)	8		7		6		5		4	
	Shoulder	Carriageway	Shoulder	Carriageway	Shoulder	Carriageway	Shoulder	Carriageway	Shoulder	Carriageway
Seal Coat	-	7	-	7	-	7	7	-	7	-
Bituminous Carpeting	-	25	-	25	-	25		40		40
Base Course	-	150	-	150	-	150	150	150	150	150
Sub Base	-	150	-	150	-	150	150	150	150	150
Improved Sub-Grade	-	200-300	-	200-300	-	200-300	200-300	200-300	200-300	200-300

Structure survey inspection frequencies:

Condition	Description	Survey Type		
		SCS-1	SCS-2	Advance Condition Survey
A	No Damage	Yearly	2 Years Interval	-
B	Minor Damage	Yearly	Yearly	-
C	Major Element Damage	Yearly	Yearly/half Yearly	As directed
D	Major Structural Damage	Yearly	As directed	As directed

The condition status of bridge and culverts based on the 2018 survey represents that 4.7% of the structures have major elemental damage with 5.1 % minor elemental damage. Rest of the structures in good and fair condition. Distribution of the condition status of the structures is shown below:



Major Structural Damage, Major Elemental Damage and Minor Damage Criteria

		Structure Components								
Observation	Major Deterioration Criteria	Abutment	Channel	Deck Slab	RCC Girder	Pier	Railing	Road Approach	Truss	Wing Wall
Scouring	> Underside of pile cap is exposed. > Visible depth of scour exceeds 1m > Volume of scour exceeds 15 m^3	Major Structural Damage				Major Structural Damage				Major Structural Damage
Leaning	> There is evidence of backfill material having being washed out. > Horizontal displacement at top measured with string line exceeds 1 in 30 or maximum 150mm	Major Structural Damage				Major Structural Damage				Major Structural Damage
Settlement	> Bridge approaches are average 100 mm lower than the deck at a distance of 1 m > Vertical displacement of superstructure is clearly visible by eye. > Vertical differential displacement of structure measured on a horizontal string line exceeds 1in 60,or 50mm over a length of 3m	Major Structural Damage				Major Structural Damage		Major Elemental Damage		Major Structural Damage
Obstruct	Obstruction cannot be removed by hand by local labour, and has to be carried out by contract or requires other special attention.	Major Structural Damage	Major Elemental Damage			Major Structural Damage				Major Structural Damage
Cracks	> Cracks in concrete are clearly visible from a distance of 3 m > Maximum crack width in concrete exceeds 1 mm > Cracks in concrete occur in critical areas, e.g. under bearing, at beam mid span. > Any cracks in steel work.	Major Elemental Damage		Major Structural Damage	Major Structural Damage	Major Elemental Damage			Major Structural Damage	Major Elemental Damage
Spalling	> Soffit reinforcement is fully exposed over a single area exceeding 1 m^2 of deck or half width of beams.	Major Elemental Damage		Major Elemental Damage	Major Elemental Damage	Major Elemental Damage				
Damaged/Missing Section	> All structural members in concrete or steel. > All holes in concrete deck. > All railing members.			Major Elemental Damage	Major Structural Damage		Major Elemental Damage		Major Structural Damage	Major Elemental Damage
Missing Bolts	Structural joints.					Major Elemental Damage			Major Elemental Damage	
Note: Any observation which does not meet the above criteria and conditions should be recorded as minor.										

Typical roads, bridges and slopes failures observed in Bangladesh are presented below:

Road Failures: Cracks 	Road Failures: Depression 
Road Failures: Edge Failure 	Road Failures: Pavement washout 
Road Failures: Pothole 	Road Failures: Revelling 

Bridge Failure: Complete Slope Failure 	Bridge Failure: Partial Slope Failure 
Bridge Failure: Scour at Pier 	Bridge Failure: Scour at Abutment 
Bridge Failure: Cracks and Spalling 	Bridge Failure: Mechanical Devices (Expansion Joints) 

Bridge Failure: Settlements	Bridge Failure: Leaning and Settlements
	

Opportunities

- LGED is responsible for a large portion of the rural roads and bridge infrastructure in Bangladesh, covering the full life cycle of the infrastructure; Additionally, a wide range of structural type, particularly in bridge design, leads a multifaceted axis of opportunities for improvement, both planning and design;
- To continue pursuing the study of the origin of the "Major Failure Modes" identified, both for Roads and Bridges, by means of specific detailed studies and research;

Recommendations

- To identify principal failure modes for Roads and Bridges through a continuous analysis of the local context practice;
- To better understand design approach;
- To develop a semi-automated spread-sheet based on Fault Tree Analysis to identify potential causes of roads and bridge failures ("Tool Kit");
- To confirm/validate key failure modes for Roads and Bridges;
    - Roads: a) embankment slope failure - static stability; b) Scour slope failure; c) Pothole; d) Pavement wash-out (inner and pavement edge);
    - Bridges: a) Structural static system (mechanisms); b) Concrete spalling; c) Concrete cracks; d) Settlement/Lining of structure; e) Foundation scour; and f) Lockdown of mechanical devices
- To amend current work on Strategic Asset Management and corresponding Asset Management Plan with an additional level "Level 6 / Observations / Weakness Sign (WS)";

3. GOVERNANCE AND LEGAL FRAMEWORK

Aim and Objectives

The aim of this section is to understand the institutional and political environment, the regulatory framework, including codes and standards, and key stakeholders within which the road and bridge infrastructure is defined.

This section´s objective is to confirm that a) it exists a well-structured governance and legal framework, b) key stakeholders´ role and responsibilities are clearly defined and well understood by all professionals, c) a competitive and robust market of engineering consultant firms and contractors do exist (capacity and capability), and d) the range of construction material (accessibility and quality assurance).

Key findings

- There is a structured regulatory system in Bangladesh, highly centralized at Government Level;
- LGED is highly structured between different departments and services requiring significant communication and coordination effort between those;
- Implication of climate change in road and bridge design is yet to be implemented consistently across the different projects and "normalized";
- No formal consultant and contractor´s Rating System for Public Works, in both the process and quality of previous works - records - ;

However

- It would seem that the Design Regulatory Framework is a "compendium" of norms, codes, regulations, manuals … (essentially driven by the AASHTO LRFD code and local regulatory technical documents) with inserts of the "Bangladesh National Building Code" (BNBC) and "Building Code Requirements for Structural Concrete (ACI 318-14)" which coherence and cross references shall be properly revisited;
- A wider access to Norms and Regulations shall be granted as well as a uniform use of the AASHTO LRFD Codes.

Governance and Legal Framework

Bangladesh is the eighth-most populous country in the world, with a population exceeding 161 million people and with an area of 147,570 square kilometers, making it one of the most densely-populated countries in the world. The country is run by a unitary government – no state or provincial government.

The administrative system is highly centralized, and most of the decisions come from the central government. Ministries' functions are governed by the Rules of Business and Allocation of Business as issued and amended by the government from time to time. Under each of the ministries there are a number of implementing agencies that implement the decisions of their respective ministries. The implementing agencies operate their businesses through their subordinate offices at district and sub-district levels.

The field offices are the deconcentrated offices of their headquarters with limited power and authority. The LGED is one of the implementing agencies under the ministry of Local Government, Rural Development & Cooperatives which also operates through its divisional, regional, district, and sub-district offices.

LGED's roles and responsibilities are driven by the Government's Allocation of Business and guided by several sectoral policies, strategies, guidelines and manuals but not limited to the following:

- Rural Development Strategy 1984;
- Rural Infrastructure Strategy Study 1996;
- National Rural Development Policy 2001;
- National Land Transport Policy 2004;
- Urban Management Policy Statement 1999;
- National Water Policy 1999;
- Rural Roads and Structures Maintenance Policy 2013;
- Poverty Reduction Strategies;
- Five Year Plans;
- Perspective Plans;
- Bangladesh Delta Plan 2100;
- Environmental Laws; and
- Bangladesh Climate Change Strategy and Action Plan 2009.

LGED also follows a number of the international conventions and treaties to which Bangladesh is a signatory - for example, Millennium Development Goals (MDGs), Sustainable Development Goals (SDGs), Paris Agreement 2015 and the Sendai Framework 2015-2030.

Bangladesh Climate Change Strategy and Action Plan (BCCSAP) 2009, Seventh Five Year Plan (2016 to 2020), Perspective Plan, SDGs, Paris Agreement, and Sendai Framework particular strategies/documents that guide LGED to consider climate change adaptation and mitigation measures as well as resilient actions in their infrastructure projects/programmes.

In general, there is no further approval required during construction of roads and bridges once it is approved by the ECNEC unless relocation of utilities is needed. But the following

cases, permission from other public sector organizations may be required while design the project:

- Permission from the Railway authority is needed in case of construction of flyover and level crossing if the road crosses the railway track.
- 'No objection' for navigational clearance- both horizontal and vertical - from Bangladesh Inland Water Transport Authority (BIWTA) have to be obtained for construction of bridges.
- Permission from Bangladesh Water Development Authority (BWDA) and Water Resources Planning Organisation (WARPO) is needed in case of construction of a new bridge either upstream or downstream at the proximity of existing barrage or dam.
- Permission is needed from the Department of Environment.
- 'No objection' is needed from the Department of Bangladesh Haor and Wetlands Development if the project is located in some specified areas.
- 'No objection' is needed from the Forest Department as the project is located in some specified areas.

Note: The key public authorities in case of bridge construction are:

- Bangladesh Bridge Authority (BBA): responsible for bridges if the total length is equal to or larger than 1500 m irrespective of national or rural road network.
- Roads and Highways Department (RHD): responsible for bridges of length less than 1500 meter on national road network;
- LGED: responsible for bridges of length is less than 1500m on rural road networks.

In addition to the above Public Authorities, Local Government Institutions such as City Corporation and Municipalities also build bridges within their jurisdiction, however, those are largely small and simple bridges.

Codes and Standards

The following Codes, Standards, and Manuals/Guidelines are used in the design of roads and bridges of LGED:

- Codes:
  - AASHTO LRFD12 Bridge Design Specifications, Sixth Edition (2012);
  - Guidelines for Bridge Design of Local Government Engineering Department - September 2018;
- Standards:
  - Road Design Standard (2004) by the Planning Commission of Bangladesh;
- Manual and Guidelines:
- Specifications:
  - AASHTO LRFD Bridge Design Specifications, sixth Edition (2012)
  - 14 C 494 Standard Specification for Chemical Admixtures for Concrete;

The LGED is currently using "AASHTO LRFD Bridge Design Specifications, sixth Edition (2012)" for design and evaluation of rural bridges. The bridge loading considers AASHTO-LRFD and **Bangladesh National Building Code (BNBC). "Building Code Requirements for Structural Concrete (ACI 318-14)"** and "ASTM14 C 494 Standard Specification for Chemical Admixtures for ConcrASTMete" are also used as references.

The BNBC is also consulted for earthquake and wind speed considerations. For designing rural bridges, the LGED is now focusing more on location, length, waterway area, hydrologic and hydraulic (stream stability, bridge waterway, foundation, roadway approaches etc.) analyses and roadway drainage system.

The LGED follows the 'Road Design Standard' introduced by the Planning Commission of Bangladesh in 2004. Recently, they have revised their road design and pavement standards as road pavements constructed according to this standard are subject to premature failure at various locations or stretches prior to reaching the design life of 10 years. Unexpected increase in traffic volume and unusual rapid changes in rural traffic patterns are identified as the main reasons behind such failures. This revised version is under process for approval by the Planning Commission.

Additionally, LGED is also studying and developing design criteria for rural bridges in coastal areas, representing about 19 coastal districts. This is mainly to address different **climate change impacts** including sea level rise, coastal inundation, tidal flooding, salinity intrusion, cyclone and storm surges. As an example, recently the LGED has taken a decision **to use higher strength marine concrete** in coastal districts from 25 MPa to 30 MPa (source: Project Appraisal Document, Supporting Rural Bridges funded by WB, LGED).

The implementation of the AASHTO LRFD Bridge Design Specification is expected shortly to enhance the safety, serviceability, constructability, bridge aesthetics and overall economic life of rural bridges.

LGED usually uses international technical standards and codes and develops their design guideline customizing the input parameters like wind speed, height of freeboard, etc. to address the impact of climate change.

LGED is also going to revise its technical design standards, specifications and related documents taking the climate factor into consideration which will be applicable for all projects and programmes across LGED. This initiative is supported by a project funded by Green Climate Fund (GCF), KfW and Government of Bangladesh.

The design unit within LGED conducts training on a regular basis to keep their engineers and consultants updated about the changes and introduction of codes, standards and local laws and regulations. For example, the government has instructed the hydro morphology study for construction of bridges of length 100m and above.

Key stakeholders' Roles and Responsibilities

In the field of infrastructures there are several actors, and the division of responsibilities are clearly spelled out in the **government orders**. To avoid any duplication of work and conflicts among the government departments there are a number of institutional arrangements like **inter-ministerial committees** at the central level, **coordination committees** both at central and field levels.

In addition, there is a mandatory requirement that any new project or revision of on-going projects should pass through the **Planning Commission** (see here below for roles and responsibilities) where coordination among stakeholders is ensured.

The Planning Commission invites key stakeholders like the Ministry of Finance, Ministry of Environment, Forest, and Climate Change, Ministry of Women and Children Affairs, and Implementation Monitoring and Evaluation Division (IMED) to take part in the discussion. Once the Planning Commission agrees to a project then it goes to the Executive Committee of the National Economic Council (ECNEC) chaired by the Hon'ble Prime Minister where key ministers are members for final approval of the project.

It has been identified that there is no regulation and enforcement for overloaded trucks.

External Stakeholders - State Agencies -

LGED's administrative offices and functional units are all internal stakeholders. For each position of the LGED organisational structure there is a formal Charter of Duties in which roles and responsibilities are clearly defined. LGED staff are involved in the whole project cycle. Relevant line ministries including Planning Commission, Ministry of Finance, and IMED are external stakeholders and their roles and responsibilities and involvement in the project cycle of development works are also predefined.

The roles and responsibilities of key external and internal stakeholders are presented below:

External Stakeholder (State Agencies)	Roles and Responsibilities
LGD, Ministry of Local Government Rural Development, and Cooperatives	Operation oversight being the LGED's parent ministry
Planning Commission	Operation appraisal and approval
IMED	Monitoring and Evaluation
Central Procurement Technical Unit	Oversight function of application of procurement legislations and management of e-GP portal
Ministry of Finance (MoF)	Operation budget allocations and fund release
Economic Relations Division, in case of Multilateral Development Bank financing project	Liaison with the World Bank, Asian Development Bank, JICA, KfW, IFAD, etc.
Comptroller and Auditor General (C&AG)	External audit of the operation
Anticorruption Commission	Corruption prevention and investigation and prosecution
Institution of Engineers of Bangladesh	Facilitate arbitration
Police Department (Traffic Control and Over)	Traffic Control

External Stakeholders - Private Entities -

Roles and responsibilities of **contractors** and **consultants** usually vary with the nature of works and services. The following tables provides the most common consultant firms around the development of an Infrastructure Road Project:

External Stakeholder (Private Entities)	Roles and Responsibilities
Engineering Consulting Firms	Assist in providing engineering technical advice and in developing engineering documentation ("Project") for approval, bidding, construction and operation and maintenance processes.
Contractors	Undertake the construction of the "Project" under the technical requirements stated in the engineering documentation by means of construction equipment, labour and material.
Quality Assurance / Quality Control Laboratories **Not present at this stage in Bangladesh. This role is performed by LGED Quality Control Unit (refer here below) -**	Independent firms responsible for auditing the construction process (material purchase, handling, storage, mixing, assembly, …) and to perform material tests, both destructive and non-destructive testing.

External Stakeholder (Private Entities)	Roles and Responsibilities
Operation and Maintenance Firms **Not present at this stage in Bangladesh. This role is performed by LGED Road Maintenance and Road Safety Unit (refer here below) -**	Undertake the Inspection and Maintenance function during the operational stage of the "Project". Duties are related to Inspection, Repairs, Replacement of parts of the "Project" to preserve the asset desired operational and service level to the Public.
Public	Users

Generally, **contractors** and **consultants**' duties and professional liabilities are well articulated in procurement related documents (Public Procurement Act 2006, Public Procurement Rules 2008, Standard Bidding Documents).

Internal Stakeholders (within LGED Structure)

Within LGED´s department structure, roles and responsibilities are as follows:

Planning Unit

The formulation and approval of development projects/programs are coordinated and facilitated. Following are the major tasks undertaken by the Planning Unit:

- Preparing of Preliminary Development Project Proposal (PDPP), Technical Assistance Project Proposal (TAPP) for newly planned projects;
- Coordination/Communication among Pre-Project Appraisal, Technical Assistance Consultant and Fact-Finding Mission;
- Participating in workshops related to approval of new projects of LGED and workshop organized by other relevant ministry of government of Bangladesh;
- Establishing linkage of LGED's development activity and future plan with existing government policy and strategies;
- Providing technical assistance to development projects undertaken by LGED;
- Acting as the focal unit for Sustainable Development Goals (SDG) implementation for LGED;
- Preparing Annual work plan on LGED undertaken development works;
- Duplication checking of road schemes during project preparation;
- Preparing Five years work plan on LGED undertaken development works;
- Create linkage among Local Government Division (for planning new projects), Planning commission, Economic Relation Division and Ministry of Finance;
- Preserving/Archiving of study report prepared by PMU's of development projects and using for future project planning;
- Approval of casual leaves of Gazetted/Non-Gazetted officers and initiating/co-signing Annual Credential Report;

Design Unit

- Provides structural design support as well as verification of design submitted by different projects. Key functions of Design Unit include:
- Preparation of Plan, Design, Bill of Quantities of different infrastructures;
- Reviewing, examining and approving the architectural and structural design prepared by the consultants under different projects of LGED;
- Provide Design Support to different Local Government Institutions like Zilla Parishad, Upazila Parishad, Pourashova etc.;
- Development of Manuals, Guidelines, Design Catalogue, Technical Specifications, Construction Methodology etc.;
- Support to Field Engineers on Design & related Planning Issues;
- Providing training on design, drawing & construction to the field engineers of LGED;
- Organizing training, workshop and seminar on professional skill development of the engineers working in the Design Unit;
- Updating Schedule of Rates for bridge works & Analysis of Rates for Bridge works;
- Carry out innovative research activity for finding cost effective & sustainable options for different infrastructure under prevailing situations in different regions of the country;
- Carry out field visit & other related activities for trouble shooting to adopt appropriate alternative design options and construction methodology when works cannot be proceeded with standard design because of prevailing particular site conditions;
- Organizing and storing design data/parameters/assumptions/drawings, reports, etc..;

Project Monitoring and Evaluation Unit

The role of PM&E Unit seems to be quite far-reaching in the evaluation of progress achieved in the project and programmes. This unit remains deeply involved in the budgetary allocation for various projects and programmes undertaken by LGED in a financial year. The unit also reviews the physical and financial progress of the projects through holding monthly regular meetings at the LGED headquarters chaired by the Chief Engineer, LGED and attended by all Project Directors and other senior officials. Providing assistance to the project directors in the release of funds from the ministries concerned is another function of the Unit.

Road Maintenance and Road Safety Unit

RMRSU is responsible for accomplishing cost-effective maintenance management and implementation of rural road and culvert maintenance programs. The major activities of LGED Road Maintenance and Road Safety Unit (RMRSU) in brief -

- Policy formulation for rural road and bridge maintenance;
- Preparation of maintenance planning, implementation, supervision and monitoring guidelines and framework for rural road and bridge;
- Formulation of annual maintenance program;
- Initiatives to accomplish different types of survey and update road database;
- Data collection and organization;
- Assessment of Annual Maintenance need and resources required;

- Preparation of priority scheme list;
- Judicious allocation of district wise resources;
- Approval of annual maintenance scheme;
- Supervision, quality control, monitoring and reporting;
- Study of existing rural road safety related laws and their compilation to help the enforcement authority regarding road safety issues;
- Preparation of guidelines, standards and designs related to road safety;
- Training and capacity building of LGED staff regarding road safety;
- Coordination for inclusion of road safety component in all important road projects of LGED;
- Install road signs and markings on route;
- Preparation of road safety education materials for users;
- Identifying the causes of accidents on rural roads;
- Road safety action plan;
- Black spot countermeasure design;
- Countermeasures considering the causes of road accidents;
- Road safety audit;
- Updating Schedule of Rate;

Procurement Unit

The main functions of Procurement Unit include, but not limiting to:

- Provide technical assistance to all Procuring Entities in LGED in order to implement both offline and online procuring activities;
- Monitor compliance with the Public Procurement Act and Rules, including other procurement procedures followed by different donor aided projects;
- Assist Head of the procuring entity (The Chief Engineer, LGED) in discharging the responsibilities vested upon him under the Public Procurement framework and Delegation of Financial Power (DoFP) issued by the Ministry of Finance;
- Help-desk support to Procuring Entities, Tender/Proposal Evaluation Committee members in processing the e-GP activities;
- Provide MIS, Server and Email ID troubleshooting services to all stakeholders (PEs, ToC, TEC Members etc.);
- Performs the duties of Organization Admin and Head of the Procuring Entity's ID on behalf of the Chief Engineer, LGED;
- Provide opinion in relation to complex procurement issues requested by the Chief Engineer, Project Directors, Executive Engineers and Upazila Engineers;
- Verify the Tender Documents, Request for Proposal Documents; Specifications, Terms of References (ToR) etc. prepared by the concerned Procuring Entities above a certain threshold.
- Issue guidance notes, instructions to LGED procuring entities in connection with the procurement matters;
- Receive and examine annual procurement plans prepared by procuring entities;
- Develop, promote and support training and professional development of LGED officials engaged in public procurement;

- Prepare any sections of documents (apart from CPTU documents) to be used in connection with the public procurement etc.

Quality Control Unit

Key Functions of LGED Central Quality Control Unit are:

- To supervise and monitor different activities of district laboratories;
- To provide technical support to district laboratories in conducting routine jobs;
- To conduct different Quality Control (QC) Test as per field requirement for high strength concrete, steel test and bitumen Marshall test etc;
- To prepare technical specification of different laboratory equipment and related machineries;
- To perform calibration of different load devices being used in LGED laboratories;
- To conduct different experimental works as per LGED requirements;
- To prepare categorized training manuals related to Quality Control (QC) issues;
- To impart training program on Quality Control and Testing for LGED, LGI Engineers and Technicians;
- To conduct quality audit on the civil works of LGED;
- To conduct test on the engineering materials of different producers;
- To conduct operation and maintenances of lab equipment;
- To plan and budget of LGED laboratory functions;

Please note that in some instances, the Quality Control Unit asks for support from University Laboratories for the validation of certain material/devices, for example Bearings and Movement Joints.

Audit Unit

Audit unit usually does not carry out any internal audit. They mainly provide support to the project director offices in drafting the reply to the queries raised by the external auditors. They also coordinate and facilitate the meeting and liaison between LGED and the office of the Comptroller and Auditor General (C&AG).

Side Note on Capacity of the contractors and consultant

No formal market assessment has been done in order to know the capacity of local contractors and the consultants. This section is written based on informal discussion with government officials and contractors. The construction market is relatively competitive in Bangladesh with exception for remote or hilly regions where the big construction firms from Dhaka are reluctant to bid due to long distance from the capital and scarcity of skilled labour, technicians and engineers. Competition tends to be more limited in such areas, but where access is not an issue competition is adequate.

Local contractors in Bangladesh are increasingly coming of age as they show strengths in terms of timely-delivery of projects as well as playing a major part in mega-tasks implemented by foreign firms. They are more self-sufficient than in the past. It is now perceived that there

is no need to depend on foreign firms to implement small- to medium-sized construction projects such as roads and bridges. The testimony could be found in various infrastructure development projects such as the four-lane Dhaka-Chittagong highway, access road to Bangabandhu Bridge over the Jamuna river and Osmani International Airport in Sylhet. This is a matter of pride for Bangladesh.

In the past when foreign firms used to build large bridges and infrastructure projects in Bangladesh, they would bring equipment from outside of the country. But most of the equipment now being used in the projects being implemented by foreign firms are being supplied by local firms.

Infrastructure Sector in Numbers

The sector posted 9.92 percent growth in 2017-18, up from 8.77 percent in the previous fiscal year, according to the state-run Bangladesh Bureau of Statistics (BBS). The sector's share to the GDP increased to 7.50 percent in the last fiscal year, which was 7.36 percent in 2016-17. The value of the economic activities in the sector was BDT 735,950 million in the last fiscal year.

In an interview, published in a widely circulated newspaper, the construction leaders claimed that some 3.43 million workers are now employed in the sector. There are about 4,000 construction firms in the country, according to the Bangladesh Association of Construction Industry (BACI), a platform of contractors and engineers. Of them, 100 construction companies have the capacity to execute projects even in a foreign country.

Contracts valued up to BDT 500 million (c. 6 million US$) are almost entirely implemented by local contractors. Contracts ranging BDT 500-1000 million are also largely implemented by local contractors, but also attract some larger contractors based in Dhaka or divisional towns. Beyond BDT 1000 million (c. 12 million US$), local contractors largely resort to JV arrangements to mobilize the required resources.

Multilateral Development Bank (MDB) funded projects costs typically range from BDT 40,000 - 50,000 million (c. 500-600 million US$), with a few projects costing around BDT 100,000 million (c. 1,200 million US$). These are largely implemented by foreign contractors in JV arrangements with domestic contractors.

There are only a few domestic national level construction contractors that have the capacity to execute these larger contracts in terms of expertise, modern equipment and management skills. Their combined market share is reportedly more than 90%. These are:

- Abdul Monem Ltd.
- Mir Akhter Hossain Ltd.
- Project Builders Ltd.
- Max Infrastructure Ltd. (Max Group)

- Bengal Development Corporation Ltd.
- Monico Ltd.

Similarly, local consulting firms have substantial experience in project management, design, construction and supervision of large and complex construction of roads, bridges and sensitive infrastructure even abroad.

Opportunities

- The implementation of the AASHTO LRFD Bridge Design Specification is expected shortly, and is strongly suggested as an essential step a) to enhance the uniformity of codes/norms to be used and b) to provide a coherent and consistent level of safety, serviceability, constructability, bridge aesthetics and overall economic life of rural bridges, at the same time as c) a wider access to the roads and bridge design norms are granted.
- To further strengthen the relationship with the Bangladesh Association of Construction Industry (BACI);
- To promote Sustainable and Resilient Infrastructure under the National Disaster Impact Assessment (DIA) Programme;
- To minimise adverse impact of Climate Change through an Hazard Lad Program Definition (ongoing), which preliminary Hazards maps will be shared for comments shortly;

Recommendations

- To implement Contractors Rating System based on proven performance, both meeting construction budget and program (Long Term), and complying with Public Regulation;
- To value quality assurance / quality control programs that are implemented by the Contractor;
- To implement incentive program to contractors;
- To develop hazard maps for Bangladesh at State, Regional and Provincial Levels;
- To strengthen the coordination with nationwide road authority (Police Department) for tracking of overloaded trucks;
- To develop a database of truck overload in LGED´s roads thru control points for a future basis of design/regulation improvement;

4. PLANNING

Aim and objectives

The aim of this section is to understand the basis of the road and bridge infrastructure planning, starting as early as LGED´s strategic infrastructure investment policy to infrastructure pre-feasibility studies (business case and hazard studies) to identify more precisely the main challenges facing government´s sustainability and resilience of public infrastructure´s investment.

This section´s objective is to confirm that a) there is a need for infrastructure investment (design-construction-operation), b) the financial mechanism is robust and well understood by key stake-holders, and c) natural and technical hazards are well understood by the designers, contractors and operators.

Key findings

- At the Planning stage, Prefeasibility Studies are essentially driven by a) Economical aspects under the "Guideline for the preparation of the pre-feasibility study of the projects in section 15 of Part B of Part 1 (March 2014)", and b) by Political strategies laid out previously during the government election period;
- Natural hazards at State, Regional and Provincial level do not yet exist;
- Each natural public agency is developing their own hazard map, including climate change considerations, but these are yet to be published for comments;

However

- Technical Risk assessment of the different projects does not seem to be undertaken at this early stage of Planning;
- LGED challenge is to balance ever growing needs with limited resources on an ever changing environment;
- Beside the above key findings, there still exists an Inadequate flow of funding.

Need for Infrastructure Investment for Design, Construction and Maintenance

LGED projects are prepared in line with the goals, targets, and priorities as set in the National Planning documents like Perspective Plan, Five Year Plans. The project proposals also take care of the needs and aspirations of the grass root level – the inputs come from various sources – LGED infrastructure database, LGED's different units including GIS and Design Unit, stakeholder/community consultations, requests from the elected public representatives including Member of Parliaments.

Once the project preparation is completed it is then presented before a Scrutiny Committee (LGED's internal – headed by the Chief Engineer). If it is decided to proceed, then the project proposal (DPP) is routed through the formal approval process as shown below:

Project Planning Flowchart

The line ministry initiates the sectoral plans and finalizes through inter-ministerial consultations. Formulation of DPP is the responsibility of the executive agencies (in this case LGED) in accordance with the sectoral plan. The line ministry (in this case Local Government Ministry) scrutinizes the DPP and then forwards to the concerned division of planning commission for appraisal of technical and financial in the Project Evaluation Committee (PEC) meeting. The member of the concerned Division of the Planning Commission presides the PEC meeting, other members include Division Chief (concerned division), representative of the Programming Division of the Planning Commission, representative of the General Economics Division of the Planning Commission, representative of the IMED of the Planning Commission, representative of the NEC-ECNEC Wing of the Planning Commission, representative of the sponsoring ministry (in this case Local Government Ministry), representative of the Finance Division of the Ministry of Finance, representative of the Economic Relations Division of the Ministry of Finance, representative of the Ministry of Public Administration, representative of Ministry of Environment and Forest and Climate Change, representative of the Ministry of Women and Children Affairs, head of the concerned Executing Agency (in this case Chief

Engineer, LGED). In addition, PEC can invite any other expert/representative if they feel necessary.

Economic Feasibility study

There is a set guideline for the preparation of the pre-feasibility study of the projects in section 15 of Part B of Part 1 (March 2014) of the Development Project Proforma/Proposal (DPP) manual prepared by the General Economics Division (GED) of the Planning Commission. This manual guides the steps and tasks to be undertaken while conducting pre-feasibility study.

The project assessment criteria are not specified as all projects are unique.

It is a mandatory requirement to submit a feasibility study report with each project proposal if the project cost exceeds Taka 25.0 Crore (approximately 3.0 million US$). **However, in LGED it is not followed consistently**.

For the foreign aided projects, the feasibility studies are carried out by the Consultants recruited by the Development Partner/LGED – and the cost is covered by the Development Partners.

For the GOB projects, there are varied scenarios. In most of the cases, instead of a new feasibility study, the GOB project proposals refer to the outcomes of the feasibility studies of similar projects that were supported by the development partners. Though few in numbers, LGED also undertakes dedicated feasibility studies (as separate study projects) with GOB funds for critical projects – especially for the large bridges and critical infrastructures. Two main reasons for not undertaking feasibility studies for GOB projects consistently are (i) sometimes managing funds becomes difficult, and (ii) skill gaps.

Technical Feasibility study

The following tasks are performed during feasibility study. Survey and investigation works are done by outsourcing of qualified professional firms. Their experts' qualifications and experiences are evaluated prior to engagement. Performance of their previous works are also verified either formally or informally.

Usually, major survey works are carried out in order to establish the size and extent of natural obstacles such as terrain, presence of lakes, rivers and other watercourses, swamps, hard rock, expansive and compressible soils, etc., and the size, location and condition of man-made obstacles such as existing buildings and structures, drains, utilities and public service installations, etc.

A. Surveys and Inventories (for existing infrastructure condition);
    a. Condition survey and inventory for upgradation project;
    b. Drainage structures type and condition survey and inventory for upgradation project;
    c. Topographical survey of road and adjacent features;
    d. Classified Traffic Counts, Origin-Destination and Axle Load surveys;
    e. Hydrographic surveys of larger rivers (for bridge design).

B. Investigative Work (for design purposes);
    a. Pavement strength investigations and assessment (sampling and laboratory testing). – Upgradation project;
    b. Categorization of pavement strength into homogeneous sections. – Upgradation project;
    c. Investigation of suitability of local materials for construction and location of quarries/borrow areas; assessment of quantities of materials present and haulage distances;
    d. Hydrological regime studies.

Hydrological Site Investigation Report

The hydrological site investigation and modelling usually carried out to assess the important road design parameters and suitable bridge location with appropriate horizontal and vertical clearance to ensure minimal obstruction to flow passage and in turn safeguard interventions. This study is mandatory in the planning stage in case of construction of bridges having the length exceeding 100m.
The objectives of hydrological site investigation are:

- To determine the highest flood level to facilitate in fixation of road crest level;
- To check the adequacy of existing bridges, culverts and cross-drainage structures;
- To calculate the hydraulic design parameter (horizontal clearance, vertical clearance, low and high-water level, drainage discharge etc.); and
- To assess the impact on the hydrological regime due to construction or rehabilitation of bridges.

Analysis of the hydrological regime is performed with supplements from developing hydrodynamic and hydrologic models using SOBEK 1D and SOBEK RR or similar software. The developed detail is always calibrated and validated against water level. Performance of each model is evaluated both graphically and statistically. For statistical performance evaluation two objective functions Nash efficiency (NSE) and correlation coefficient (R^2) are used.

Geotechnical Site Investigation Report

Geotechnical investigations for structural foundations of bridges and major structures (borehole sampling and laboratory testing) and Geotechnical investigation of local sources of construction materials (test pit sampling and laboratory testing).

The development of geotechnical investigation works in Bangladesh is still at an early stage of development and sophistication, and contractors have limited knowledge and experience in the sampling and testing of soils in accordance with standard test procedures. Except few, they did not seem capable of obtaining undisturbed sand samples from any location, or clay samples from beyond 10 m depth. For GoB fund projects, sub-soil investigations are done according to the requirement specification. But, the specifications are fully complied for foreign aided projects. In such a case, previous study reports like pre-feasibility, feasibility and even detailed design reports are considered and data and information are verified randomly. Most of the cases, the whole procedure needs to be redo.

Slope stability Report

Average embankment height of rural roads is 1.25m (RSDMS, 2018). Maximum slope height is 10m. Considering cost effectiveness, the availability of construction materials and skilled workers, 10 methods have been applying for side slope protection work in Bangladesh, including grass turfing, geo-jute, gunny bags, synthetic geotextiles, gabions, long-rooted vegetation, concrete blocks and palisading work with concrete posts.

Topographical Site Investigation Report

LGED usually do not perform topographic surveys in designing of geometry of roads unless land acquisition issue is involved. Recent trend has shown that topography survey is done in case of upgradation of road geometry capacity as the Government needs to acquire public land adjacent to existing road alignment. But, in the planning stage, the general arrangement (GA) drawing for the bridge is done based on a topographic survey.

However, before commencing the topographic survey, a preliminary alignment is drawn on satellite imagery following the Design standards. The topographic survey is carried out by Total Station, GPS and Auto Leveling Equipment.

The topographic surveys always tie into the Bangladesh national grid. Prior to the survey of topographical details, a polygonal traverse is set. Permanent traverse points by concrete pillars are established, numbered and surveyed. In addition to the tachometric survey all traverse points were leveled and connected to the national elevation system. The existing road centerline, cross sections and the proposed corridor of the new carriageway are surveyed in usually 50m intervals, which are reduced to 25m or less when required by side constraints (e.g. at junctions, built-up areas). The survey also captured topographic details like existing roads, tracks, drainage structures, buildings etc. Available Highest Flood Levels along with year of occurrence were recorded.

Survey data from the recording unit are downloaded on the computer using survey software. Initially, these downloaded files are checked for survey accuracy and codes. Survey codes are used to capture different field features in different layers in the computer model. These corrected files are then used to produce a survey map. The survey maps were then further edited to prepare the Digital Terrain Model (DTM). The Benchmark (BM) information collected from Survey of Bangladesh and used for survey is always appended as annex in the report.

A. Preliminary Design Work
    a. Road alignment design;
    b. Pavement design;
    c. Design of bridges, culverts, overpasses and elevated roadway structures, etc.
B. Other Work at Feasibility Study Stage
    a. Cost Estimates;
    b. Traffic Projections;
    c. Approach to Contract Packaging;
    d. Road Safety Audits;
    e. Road Inventory database and digital mapping for use with Geographic Information System (GIS);
C. Economic Feasibility (as described earlier)
D. Environmental, Social, Resettlement and Indigenous People Assessment (refer here below)

The consultant is usually engaged for feasibility study as well as detailed engineering design for the project, the consultant therefore carries out, at the feasibility study phase, surveys and investigatory work to the level of detailed design. However, occasionally, some additional surveys and investigatory works are required to conduct at the detailed design phase to meet the needs of detailed design. Included in this work are detailed assessment of condition of existing road, structure, pavement, drainage capacity and adequacy of existing structures; topographical and hydrographic surveys; geotechnical investigation of subsoil; traffic and axle load surveys; soil and materials sampling and testing; road safety audits; collection of secondary data and reports from different sources, etc.

Financial Mechanism of LGED

The finance for all of the LGED projects comes from the central government budget.

The Government of Bangladesh prepares two types of budget annually – one is Development Budget, and another is Non-development Budget – both need approval by the parliament. The Development Budget supports all the development projects (capital expenditure) while the Non-development Budget covers the recurring expenditures like salaries, and maintenance activities. In addition, the government uses another instrument called 'Mid

Term Budgetary Framework (MTBF) – a three year rolling budget. The MTBF is a budgeting approach that links Government's policy priorities to resource allocations and resource allocations to performance. It emphasizes the efficient use of limited public resources (both development and non-development).

The MTBF prepared by the Ministry of Finance provides an indicative resource allocation to each ministry over a period of next three years. Now, it is the responsibility of the respective ministry how to distribute that allocation among the departments and agencies under its domain. In case of LGED, the administrative ministry is the Local Government Division (LGD). Under the LGD, there are several departments and agencies – LGED is one of those and the largest. This procedure ensures that the LGED gets its funding for its projects.

On the other side, the Planning Commission is the authority for approving development projects. In the approval process there is little focus on the budgetary allocation of the MTBF. Although it is the responsibility of the LGD to confirm that the proposed development project cost can be accommodated within the MTBF ceiling, however, in most cases it is done very loosely. Usually, the LGD submits a certificate with every project proposal that the project cost will be adjusted within their MTBF ceiling. In reality, there is a huge gap between the MTBF ceiling and aggregated project costs under the LGD portfolio. It happens as the LGD is subject to tremendous political pressure (which is not the case for other ministries) to take more projects – in particular the rural infrastructure projects.

LGED had been receiving adequate funds for its projects; however, the situation has changed for the last couple of years. Now LGED projects are heavily impacted because of the mismatch between project costs and budgetary provision. As a result, many projects are suffering from inadequate funding – leading to both time overrun and cost overrun. Usually the typical implementation period of LGED projects is 5 years. As there is shortage of year wise funding, the implementation period of the projects is getting extended to 7 to 10 years. As a consequence, the infrastructures built in the initial years of a project are not under maintenance care and are getting deteriorated. [*Note: unless a development project is completed, the infrastructures built under the project cannot be transferred to non-development budget (maintenance programme)].*

The fund required for maintenance is also inadequate (22 % of the requirement).

As the demand side of the rural infrastructure is very high, now the Local Government ministry is pursuing the Ministry of Finance to increase the MTBF ceiling.

Project Processing at LGED

The Planning Unit of LGED is responsible for processing all the project proposals – in all pre-implementation phases - from concept to approval. But, as it is acutely under-staffed, in practice, the unit is now playing an *'assisting and facilitating'* role.

As identified by the Chief Engineer, a particular project(s) preparation assignment goes to a particular officer(s). The assigned officer works closely with the Planning Unit till the project is approved by the Executive Committee of National Economic Council (ECNEC) headed by the Prime Minister.

Environmental Impact Assessment (EIA)

The issue of environmental compliances for development projects are guided by the Bangladesh Environmental Conservation Act 1995, and Bangladesh Environmental Conservation Rules 1997. In Bangladesh, the EIA process is generally conducted in four tiers – a) screening, b) scoping, c) initial environmental examination (IEE), and d) detailed EIA. This latest stage depends upon the extent of potential adverse impact on the environment and therefore not mandatory for all projects. However, to reach IEE level is mandatory for all projects.

In case of aided projects, Development Partners' own environmental guidelines are also followed (they have different categories). LGED has developed its own environmental guidelines and manuals for its staff to undertake the environmental tasks during project preparation and at implementation stages. The EIA Report is included in the DPP documentation.

Hazard Aspects

Not assessed at this stage. Very few projects to implement the Hazard Assessment.

Hazard Assessment Platforms

Bangladesh is considered one of the most vulnerable countries in the world to various hazards including climate risks. Different studies claim that natural disasters, like cyclones and floods, cost Bangladesh an average of 1 percent of GDP each year. Public infrastructure coverage to protect lives and assets from these disasters has significantly expanded since the 1960s, as the government has invested more than 10 billion US$ in structural assets and non- structural assets. Nevertheless, there are a number of issues that need to be addressed. Existing infrastructure in Bangladesh remains vulnerable to the impacts of climate change: Prolonged heat waves and intense precipitation put road pavements under stress and overload urban drainage systems; more severe tidal surges and floods may erode road bases and bridge supports; higher wind speeds of storms and cyclones impact on building structures – just to mention a few of them. Many roads, bridges and other physical structures were constructed at times when there was not yet full awareness for the effects of climate change.

Even if this infrastructure is repaired, rehabilitated or upgraded today, climate change is usually not taken into account systematically.

On an institutional level, the large national agencies responsible for infrastructure planning, construction and maintenance do not follow a systematic approach of resilience outcome. Additionally, climate change-related risks (e.g. higher flood peak levels, higher peak temperatures) are not systematically taken into account.

LGED does not have comprehensive vulnerability maps in terms of natural and technical hazards across the country. However, in some cases, it consults hazard-related information and tools developed by other institutions. For example, seismic zoning maps as embedded in Bangladesh National Building Code (BNBC); Flood map produced by Water Resources Planning Organisation (WARPO); Flood Inundation Map produced by Flood Forecasting and Warning Centre (FFWC). Also there are other institutions in the market who are involved in providing policy advice and scientific data related to hazards.

The Center for Environmental and Geographic Information Services (CEGIS) and the Institute of Water Modelling (IWM) – both institutions of the Government of Bangladesh – provide scientific data and tools for assessing climate-related risks and impacts. Among think tanks, the Bangladesh Centre for Advanced Studies (BCAS) or the Centre for Global Change (CGC) have a long track record of offering independent climate policy advice. Many Bangladeshi Universities offer relevant expertise that may need to be tapped during the project, such as BRAC University with its Centre for Climate Change and Environmental Research (C3ER), Independent University with its International Centre for Climate Change and Development (ICCCAD) and the Bangladesh University of Engineering and Technology (BUET) with its Institute of Water and Flood Management (IWFM) and its general expertise on infrastructure designs and materials. LGED has close linkages with all these national players.

In spite of the presence of the above-mentioned actors, LGED faces a great challenge in planning and designing their local infrastructures. Because, most of the maps and products of the above-mentioned institutions are at global, regional, and national scale. To use those products it is necessary to tailor the global/regional/national scenario into local context - which is absent at present.

In order to overcome this constraint, LGED is going to implement one project 'Climate Resilient Infrastructure Mainstreaming Project (CRIMP) funded by the Green Climate Fund, German Development Bank (KfW), and Government of Bangladesh (GOB). Under the CRIMP, a centre for excellence [Climate Resilient Local Infrastructure Centre (CReLIC)] will be established. The CReLIC will provide the missing link for effective mainstreaming of climate

factors in the infrastructure portfolio of LGED. It will fill the gap between the increasingly diverse and competent landscape of think tanks and scientific institutions that provide policy advice and scientific data in Bangladesh on one side, and project-specific innovations and best practices generated within LGED on the other side.

Core function of the CReLIC will be the continuous internal provision of up-to-date climate relevant data and information through user-friendly ICT-applications and the systematic application of climate impact assessment for LGED standard infrastructure types. The CReLIC will bring together meteorological and climate macro-data with engineering know-how, specific institutional experience of LGED and field level data to provide an integrated knowledge base for the development of guidelines, standards and procedures and even specific project proposals.

Opportunities

- LGED is a highly structured public authority to provide response to a wide range of infrastructure services across their design life; planning, design, procurement, inspection and maintenance are key stage along the Design process of an infrastructure, including the different layers of quality assurance and quality control, and auditing processes; To streamline the process is of essence under the tight operational and financial constraints;
- To support economical and socio-economical growth through a strategic infrastructure development plan that is consistent with state and regional growth strategy;
- Definition a resilient long term infrastructure investment strategy, agreed by political parties, and that promotes private investors;

Recommendations

- To undertake a Workshop with a representative sample of External and Internal Stakeholders, identified by UNOPS/LGED (15-25 Participants) to identify strength and weakness into the Planning-Design-Procurement-Construction-Operational Processes; these strengths and weaknesses will be developed in a consensus across the different stakeholders for the benedict of the road and bridge transport sector;
- To develop technical pre-feasibility studies at Planning stage to further narrow down the project risks and uncertainties, both in cost and construction program;
- To streamline the budgetary fundings once approved;
- To enforce the implementation of the DIA (Disaster Impact Assessment) as currently planned by the GoB to enhance Environmental Impact Assessment and climate change considerations;

5. DESIGN

Aim and objectives

The aim of this section is to understand engineering consulting approach to road and bridge design, form a holistic multidisciplinary and life cycle approach to infrastructure. An efficient design comes from the result of good understanding of social infrastructure needs, local hazards, including climate change considerations, potential vulnerability of the structure and local construction practice, both material and construction techniques.

This section´s objective is a) to confirm whether the design is engineered and meet national regulations and/or international good practice, b) to confirm whether the road and bridge design/typology is appropriate for the local hazard and quality / availability of construction material, and/or differ from region to region, and c) to confirm whether the construction documentation includes comprehensive drawings, including construction sequence drawings and material specifications to international good practice industry level.

Key findings

- No chartership certifications and continuous learning are required for a road or bridge designer, conversely to the building designer;
- LGED has developed an internal career-path to "excel" in design excellence;
- The **Superintending Engineer** (designer) is the chief official for approval of designs and ensures a) quality control, b) safety, c) economical project viability, d) project sustainability and durability strategy, e) respond to policy matters, f) defines construction stages and g) defines/clarifies ethical aspects necessary to attain and maintain the highest level of quality in infrastructure design process;
- The Executive Engineer is legally responsible for the design of roads and bridges.

However

- Design process of all roads and bridges are centralized on the SuperIntendent Engineers and seems to create a "bottleneck" in the design process and limit the pro-activeness across road and bridge engineers;
- Building Designers shall comply with a minimum of seven (7) years of full-time proven practice and a pre-established training curricula;

Additional Feasibility Studies

As part of the Design Stage, there may be the case for additional feasibility studies in order to obtained further information/detail in order to reduce potential risks and optimize the design of the future infrastructure (road or bridges); These additional studies are typically related to:

- Geotechnical Site Investigation;
- Hydrological Studies;
- Validation of the Topography;

Bridge and road Integrated Design (Run-off water management)

Rain water drop pipe is provided on either side of the bridge carriageway to run-off the storm water. But in most cases these outlets are blocked with debris due to absence of routine maintenance. Therefore, embankment erosion is common near the abutment and wing walls of the bridge. Height difference between deck slab and approach road frequently is seen in rural roads. Application of appropriate water resource management plans are not observed. In case of **foreign aided** projects, **feasibility study** is carried out to determine the **technical and economical** feasibility of the project, while also taking into account its environmental and social impacts in order to develop a project document for an investment project.

Under the GoB Funded Projects, the GoB has recognized the importance of the technical feasibility studies prior to the Design Stage;;

Design Stage

Upon receiving the request from the Project Directors (Executive Engineer) and any other functional units through the Chief Engineer, (refer here below for Engineering Ranking within LGED) the design unit of LGED starts developing a work plan and distributes the tasks needed to perform at design stage. Normally the design team follows the sequence as below:

a) Apprehension of the design assignment from appraisal data, soil report and topo survey;
b) Planning discussion with Superintending Engineer (Design);
c) Field visit (if required);
d) Preliminary design;
e) Confirmatory soil boring report on foundation;
f) Draft Final design;
g) Field validation;
h) Final Design.

In case of detailed design of roads and bridges, LGED follows their own customized road design standards and bridge design manual which have been developed based on international codes [AASHTO, Transport Research Laboratory (TRRL) and Indian Road congress (IRC)] and standard practices. These are the living documents and customization is done as and when required.

Tender Technical Documentation

Preparation of tender documents is generally completed in the detailed design phase.

In the event of a foreign investment. development partners' procurement procedures always governed (e.g. WB, ADB, JICA). Please note that all development partners have agreed to follow the country's procurement law/rules should the procurement be done through National Competitive Bidding (NCB) method in Bangladesh; For procurement under GoB funded projects, the country's public procurement act/rules apply.

Additionally, in both cases, Tender Data Sheet (TDS) and Particular Conditions of Contract (PCC) are customized according to the location, size and nature of procurement. General and particular specifications include material specifications and construction method, detailed drawings, design brief and bill of quantities which are appended to the tender document. Detailed design calculations with the objective to enforce an independent calculation by the Independent Engineer is not appended in tender documents. The detailed calculation is provided to the awardee contractor should the design change.

Construction sequence drawings are not always provided. This becomes important when designing hyperstatic structures to avoid locking stress which superimposed with the live load surcharge could exceed the section capacity of the structure. Therefore, it is recommended to always include a construction sequence drawing, even when multi simply supported spans are designed.

Working drawings are not always developed by the contractor unless stated in the particular specification document, which requires review and approval by the Project Director in consultation with the Design Engineer.

In the event of a design change, a procedure is in-place which includes the reason for the change and technical justification of the new design. LGED Design unit then reviews carefully and recommends to the Head of the Procuring Entity (HOPE) for approval.

Project Review

The project director is mainly responsible for preparation of tender documents. Once the design and drawing is ready, the project director office compiles a tender document incorporating the tender data sheet, particular condition of contract, general and particular specification, BoQ, design and drawings.

- Package 1: Drawings + Design Brief + Set of Calculations:

Following Design Engineers work, the above-mentioned technical documents are reviewed and approved by the **Superintending Engineer**; This review is based on the Superintendent

Engineer´s experience and does not generally include an independent analysis/assessment of the design work. This review is essentially an internal LGED Procedure but does not relieve the Design responsibility of the Executive Engineer.

Please note that in some instances, the design may be reviewed by third parties such as University Experts;

- Package 2: General and Technical Specifications Documents:

There is a **specification review committee** consisting of representatives from different functional units of LGED. The project director cannot use the specification unless it is validated by the specification committee. In case of a special type of procurement, the specification committee can co-opt expatriates on subject matter.

Simultaneously, and in order to get all review comments by all interested internal departments, the chief engineer forwards the tender documents to the procurement unit for seeking their opinion prior to the final issue.

Upon receiving comments from all parties and making the necessary adjustments, final approval from the Specification Review Committee is requested. Following this approval, the project director forwards the tender documents to the Head of the Procuring Entity (HOPE) (usually the chief engineer) for engaging the Tendering Process.

Professional Engineer (P.Eng.) Qualification

For development of the "Professional of Engineers" (P.Eng), the Institution of Engineers in Bangladesh (IEB) has implemented the Bangladesh Professional Engineers Registration Board (BPERB) in 1999 by amendment of the constitution of IEB. By-Laws were developed since then and in 2001 BPERB has been functioning uninterruptedly.

The BPERB has established the standards that will be required for an engineer to qualify as P.Eng. in order to operate within Bangladesh. PEng certification is issued upon submission and acceptance of a 2000-word report demonstrating key knowledge, skills and understanding of the engineering work environment.

The applicant often is interviewed by the panel for clarification of the issues raised in the 2000-word report and to confirm that the core objectives have been achieved by him/her. It requires continuous learning. **This P.Eng. certification is not a mandatory requirement for a road or bridge designer**.

Most of the design engineers have masters in structural engineering. In case of complex civil works, foreign consultants are hired to assist the local team.

Note: In the residential and buildings industry in Bangladesh, structural engineers to become a licensed engineer (PEng), it requires 7 years of full time post graduate work experience and satisfies training objectives as well. As stated earlier, for road and bridge infrastructure (civil works), there is no specific professional engineer qualification required.

Excellence of Professionals - Career Path at LGED

After recruitment, they are posted in the design unit as Assistant Engineer. And over the time, upon their interest, requisite training (in country and abroad) are provided to be able to be considered a Road or Bridge Design Engineer.

The LGED owns a strong and well-equipped design unit at its Headquarter headed by a Superintending Engineer (Design). Under his administration, there are two (2) design sections: 'Bridge Design Section' and 'Building & Road Design Section' each headed by an Executive Engineer

Superintending Engineer

The Superintendent Engineer allocates business to the Executive Engineers and provides them all sorts of guidance relating to a) quality control, b) safety,c) economy, d) durability, e) policy matters, f) workability in the construction and g) ethical issues necessary to attain and maintain the highest level of quality in design work.

The Superintending Engineer (Design) is the chief official for approval of designs.

A series of in house and abroad training on advanced design technology are included in their training calendar to make their design team competent with the latest development in terms of technology, codes and practices. Staff for the design unit are selected after reviewing their academic career, and also on the basis of their own interests..

Each Executive Engineer leads a group of structural engineers, architects, electrical engineers, plumbing engineers and other support staff.

There is a mechanism for knowledge transfer while they work together with consultant experts.

Executive Engineer

He is legally responsible for the design of roads and bridges. The Executive Engineer design, review and sign-off all technical documents for Tender Stage.

Effectiveness Roles and Responsibilities

The Engineers under the leadership of Executive engineers are designated as Senior Assistant Engineers or/and Assistant Engineers. They are the key persons who analyse structures, perform calculations and finally accomplish the design work. Structural design, drawings and detailing with the aid of consultants, drafting & support staff are also done under their supervision. Executive Engineers are the last level examiner of all design calculations and procedures in detail. They provide technical guidance to their junior colleagues or consultants in performing their job following the state of art design principles. Bridge component-wise tasks are clearly assigned among the design engineers. So, they can be specialized in respect of superstructure, substructure, foundation, construction materials, drainage, etc. The group of consultants are often engaged to support the LGED design team as the huge volume of design works need to be delivered within a defined timeframe of the project.

Despite advanced training provided to design engineers and recruitment of competent consultants, the performance in terms of innovation is not satisfactory. For instance, long spanned bridges with single girder beyond 60m, cable stayed, arch designs etc. are now in high demand and few of the design team have such expertise.

Opportunities

- To support LGED in the definition of Resilient Infrastructure Design and Post-Disaster Risk Assessment;
- To promote Sustainable Development;
- To support LGED in the definition of "Build Back Better" (BBB) Strategy;
- To enforce QC Processes into the General Specification Document (i.e.: Review and Approval Process, Technical Document Traceability, …);
- To strength the Continuous Learning Path at all Engineering Category Levels (Career Path at LGED) and National and/or International Certification Programmes ;

Recommendations

- To define design requirements for three (3) major Hazard Loads (River Flooding, Wind, and Temperature);
- To perform an international review of LGED´s Own Customized Road Design Standards (Manuals and Drawings);
- To propose examples of BBB following the assessment of bridge and roads pilot cases ;
- To develop QA Manual for LGED (as a whole entity);

- To strengthen a continuous learning path (specific training programs - 2 years working program) at all engineering category levels (career path at LGED) with national and/or international certification programmes be implemented;
- To develop consistently Construction Sequence Drawings as part of the Tender Drawings Documentation;
- To request consistently Contractors to develop Working Drawings for Project Director´s Review and Approval;
- To developed detailed and recorded Technical Design Review Processes;

6. PROCUREMENT AND CONSTRUCTION

Aim and Objectives

The aim of this section is to understand how the construction environment functions, what are the typical procurement methods for achieving the most economical-technically advantageous tendering process mechanism for a given infrastructure typology.

This section´s objectives are a) to confirm procurement and construction management processes (Engineered Procurement Construction - EPC - Process or Fast Track Project – Design and Built Projects-) and b) whether a clear role and responsibilities are clearly defined and understood by all the stakeholders, including construction quality assurance and quality control processes. It is important to address any incentive measures to contractors´ work such as clear payment schedules.

Key findings

- Public Procurement is regulated by the Public Procurement Law, 2006 (PPA, 2006), Public Procurement Rules, 2008 (PPR, 2008) and Electronic Government Procurement Guidelines 2011;
- Public Procurement allows for several procurement methods, which largely depends on the capacity of the local/national market;
- One Stage Two Envelope Method (OSTEM) Procurement system is the most widely used within LGED;
- Most of the procurement (approx. 97%) is processed in e-GP (e-Government Procurement) system following the Cabinet Decision using the national e-GP Portal;
- There is an acute scarcity of high quality natural materials for use as aggregates, bitumen, and steel concrete reinforcement;
- Neither Pre-tensioning nor post-tensioning high tension wire is produced in Bangladesh and technology requires foreign expertise.

Procurement Method and Awarding Method

LGED, as a public sector Engineering Organization, follows the Country Procurement System, which is guided by Public Procurement Law, 2006 (PPA, 2006), Public Procurement Rules, 2008 (PPR, 2008) and Electronic Government Procurement Guidelines 2011, in procuring the goods, works and consultancy services.

The country procurement system allows several procurement methods for procurement of works, goods and services. In case of procurement of works, the commonly used methods include:

- One Stage Two Envelope Method (OSTEM);
- Limited Tender Method (LTM), and;
- Open Tender Method (OTM).

The selection of method largely depends on capacity of the local/national market, volume of works to be procured and value of the contract. LTM is mostly used to procure small contracts of value not exceeding BDT 30 million. The procedures of the LTM method is also simple - the tenderers have to quote their price within ±5% of engineering estimates. Other Methods do not have any financial ceiling. In the case of OTM, there is no limit but the offered price beyond ±10% of engineering estimates are not considered for evaluation.

The OSTEM is widely used in most of the departments including LGED. In OSTEM, the bidders prepare both technical and financial bids in two separate inner envelopes - one for technical bids, and the other for financial bids - then they submit one outer envelope that contains the two inner envelopes. Technical evaluation takes place in the first stage; and, in the second stage only those financial bids are opened whose technical bids are qualified. Award is given based on the *'**lowest evaluated price**'* - *not the* ***'lowest price'***. In the technical evaluation, bids/bidders must fulfill the mandatory requirements in regards to technical and financial capacities, legal requirements, requisite experience, and eligibility criteria as pre-set in the tender document. Evaluation of tenders is done by the **Tender Evaluation Committee (TEC)** formed as per provision of the procurement laws. Each of the procurement entities must have at least one TEC. The TEC consists of 5-7 members of which at least two (2) members are drawn from other external ministries.

The country procurement laws also include a provision for 'pre-qualification' in case of complex and/or large construction projects.

Most of the procurement (approx. 97%) is processed in e-GP (e-Government Procurement) system following the Cabinet Decision using the national e-GP Portal.
It is a mandatory provision by the law that each department ensures that the Annual Procurement Plan (APP) is prepared, approved and published through the e-GP System. The APP is also published in the respective department's website. In fact, this is a kind of 'opportunity disclosure' in advance for the potential bidders. Likewise, in due course of time, specific tenders are also hosted in the e-GP system, the department's own websites and also published in the widely circulated national newspapers. E-Tender is floated in the national e-GP portal giving sufficient time for preparation to the tenderer. Tender opening, Evaluation, Approval Process, Issuance of Notification of Award, Contract Signing etc. are done through an online process. Proper publication is ensured in the national dailies as well as e-GP Portal, LGED website and Central Procurement Unit website. LGED as well as all the public sector organizations publish the debarment information in case of debarring the contractor or

consultant for engaging in fraudulent, corruptive, collusive, coercive or obstructive practices as per section 64 of PPA, 2006, in the CPTU website and eGP Portal which are crosschecked before finalizing the recommendation of Evaluation Reports to the approving authority.

Recruitment of consultancy services and nominal numbers of works procurements as per requirement of development partners are done through off-line procurement process.

Furthermore, the procuring entities arrange pre-bid/pre-proposal meetings for the interested bidders to make the provisions clearer and more understandable. These instructions are reiterated during handing over the sites to the contractors and in the kick-off meeting with consultants.

Effective Roles and Responsibilities

LGED is a decentralized organization having more than 90% manpower working at sub-district (Upazila) level headed by Upazila Engineer. He leads the team of 20 well-trained staff including 1 Upazila Assistant Engineer, 5 Sub-Assistant Engineers, 4 Work Assistants, 1 Community Organizer, 1 Surveyor and others. So Upazila Engineer and his team is the main working force in implementing the contracts. They supervise and administer the contracts and certify the payments to the Procuring Entity. Finally, the PE (the district Executive Engineer) pays the contractor in accordance with contract terms and conditions. In case the Upazila Engineer is the Procuring Entity, they procure, supervise, administer the works and finally to the contractor in accordance with contract terms and conditions.

In 2017, LGED developed and published a Contracts Management Manual and conducted a series of training to LGED engineers. The manual had been distributed to different offices and to some extent being used as reference. The challenge is on the consistency of the use of the processes as recommended in the manual for which this assessment was not able to cover.

The Executive Engineers at district and Sub-district (Upazila) Engineers hold management meeting on a regularly manner or when required with the Contractors/suppliers, consultants, if any, and staffs and discuss issues related to problematic issues, design, specifications and progress and ensure smooth implementation of the contracts.

Design Change Procedures

In case of rectification and/or material change (refer to chapter of Material / Scarcity of Construction Material), the contractor is asked to submit the rectification proposal inducing design up on identification of defects which needs rectification. Then, the District Executive Engineer forwards the contractor's design to LGED's central design unit for their vetting. Then it is sent back to Upazila Engineer to execute the rectification works. In some cases, design

engineers from the central design unit pay visit the sites prior to concur. There is a variation approval procedure exists and these are done in coordination with the contractor and other potential stakeholders.

Material

In the supply contract, the suppliers are needed to supply samples before final order is to be placed. But in Construction Contract normally the Procuring Entity (PE) or Project Manager (PM) visits the stackyards of the contractor and collect the sample of the materials and test in LGED district or central Laboratory or in case of unavailability of test facility in LGED Lab than send to BUET or any other university Lab where the facility is available. After the confirmation, the contractor may proceed. Normally PE or PM is the approving authority.

Scarcity of Construction Materials

Aggregates

There is an acute scarcity of high quality natural materials for use as aggregates in pavements and concrete, throughout Bangladesh, due to the geological landform of the land. Although some sources of inferior rocks are utilized in the production of aggregates suitable for use in underneath layers in pavement construction, to obtain sufficient quantities for this production is difficult and sources are limited.

An alternate source of sub-base and base materials in Bangladesh is aggregate produced from crushed "over burned" clay bricks. These crushed "over burned" clay bricks can achieve LAA values in the range of 40-45. Bricks are available abundantly throughout Bangladesh and are extensively used as an aggregate source. Brick manufacturers can produce different qualities of brick according to the use requirements. Brick is not agriculture and environment friendly as clay is used to make bricks and it is burned into a brick kiln which emits 'particulate matters' into the air. Thus, the Government has taken legal initiatives to discourage the use of such types of bricks. As a result, machine made brick factories have been expanding across the country rapidly.

Aggregates produced for use in Base course, Asphaltic Concrete and Cement Concrete; require rocks which possess high quality engineering qualities. Due to geological formation most of the lands in Bangladesh are plain agricultural land. It is an alluvial deposit of silt or silt clay mixture. Rocks required for good quality aggregates are not abundantly available. Rapid development of infrastructure in Bangladesh, demands very large quantities of rock aggregates.

The following quarries are the main sources of hard rock in Bangladesh:

- Sylhet source (Jaflong, Bholagonj, Guineghat).
- Modhayapara in Dinajpur District.
- Panchagar in Dinajpur District.
- SherpurDistrict (Jhenaigati).
- Banderban and Khagrachari Districts.

Sylhet and Madhayapara are proven quarries from which quality stone for use in the production of high quality concrete and asphalt works is obtained. Stone from Jhenaigati and Banderban is of comparatively inferior quality but is suitable for use in pavement construction as base and sub-base materials.

Unfortunately, the total production of all the above-mentioned sources is insufficient to meet the demand for hard rock required for the production of aggregates for use in all construction activities in Bangladesh.

To meet the current demand, hard stone for production of aggregates is imported often into the country. For the implementation of any large project in Bangladesh, it has been observed that contractors import hard rock for aggregate production. The source for hard rock imported into Bangladesh is the neighboring country of India, and hard rock from this source has been used extensively on different large projects in Bangladesh.

Bitumen

Economy and performance of bitumen bound pavement layers is highly dependent upon the quality and optimal use of bitumen. In Bangladesh generally, penetration grade bitumens are used in asphaltic pavement works. Penetration Grades of 60-70 and 80-100 are commonly in use. The construction industry in Bangladesh exerts a high demand for bitumen. Because Eastern Refinery, the only bitumen producing company in Bangladesh, is unable to cope with the demand, Bangladesh has to import Bitumen. Importers generally obtain Bitumen from India, Iran and Singapore.

Cement

Cement is abundantly available in Bangladesh. Although some of the raw materials for cement production are totally absent in Bangladesh, a sufficient number of cement companies have been established through the importation of raw materials. The world famous company La Farge has set up a cement factory in Sylhet and imports limestone from India. This is a privately owned limited company. Most other cement companies import clinkers as raw material and grind the clinker with gypsum to produce cement. A new trend has been developed by the addition of fly ash or blast furnace slag during grinding. The products are sold as Portland composite cement (PCC). PCC is less expensive than Ordinary Portland Cement (OPC) which has been classified as Type-1 cement in ASTM classification. Due to the

larger market, most of the Bangladesh companies produce PCC and it is difficult to obtain Ordinary Portland Cement (OPC, Type-1) in the open market unless a special order is placed. Other types of cement such as sulphate resistant cement and rapid hardening cement are not produced in Bangladesh. The cement producing companies in Bangladesh have shown a low interest in producing these cements even after special orders have been placed, presumably because their manufacturing process will require modification and the quantities ordered may not make the instigation of these modifications very lucrative or worthwhile.

Concrete Reinforcing Steel

As with cement, there is no raw material (iron ore) available in Bangladesh to produce steel, but a number of steel mills have been established in the country by Bangladeshi entrepreneurs. Some steel mills produce good quality rebar required for the production of reinforced concrete. However, most of the mills produce the rebar from scrap iron. Generally, rebar made from scrap iron is not of good quality because the producer cannot maintain a constant chemical composition and consequently the physical requirements pursuant to the specification. The reputed steel mills that produce the rebar from billet steel are:

- Bangladesh Steel Re-Rolling Mills Ltd (BSRM)
- Kabir Steel Re-Rolling Mills Limited (KSRM)
- Rahim Steel Mills Co. (Pvt.) Ltd (RSM)
- Anwar Steel Mill
- AbulKhair Steel Mill (AKS)
- Bashundhara Steel Mill.

All the mills are situated in well communicated locations and are capable of supplying sufficient quantities of steel to satisfy the requirements of the project road.

Pre and Post Tension Wire

Neither pre-tensioning nor post-tensioning HT wire is produced in Bangladesh. These materials will need to be imported for the project.

MechanIcal Devices (Bearings and Movement Joints)

Standard expansion joint items/materials are not manufactured in Bangladesh. Such items/materials will need to be imported.

Some entrepreneurs have started to produce bridge bearings (specifically neoprene bearings) and these have been used in some important projects in Bangladesh. The bearings were tested by BUET and results were found to be satisfactory, but long-term performance is still unknown.

Quality Assurance and Quality Control Laboratories

A Quality Assurance Plan (QAP) is prepared at the beginning of the project to achieve, sustain and improve the quality of service and to give assurance that internal controls exercised are effective and adequate and fully conform to the code and specifications, It includes plans/procedures for different field studies, engineering surveys and investigation, design, construction, environment and social assessment, economic and financial analysis, drawings and documentation; preparation, checking, approval and filing of calculations, identification and traceability of project documents etc. Generally, for all major projects, a quality assurance plan is developed by the consultant and provided to the contractor and the employer. Methodology and procedures are set out for compliance methodology. The consultant regularly submits the compliance report on any items of work. On the basis of compliance of the report, the payment to the contract for any item of work is considered acceptable.

In case of supply contracts, usually an Inspection and acceptance committee is formed when the supplier informs that the products are ready for supply. The Inspection and acceptance committee checks whether the product meets the threshold of the specification. After getting clearance from the committee, the supplier may proceed with the real supply. In case a product is supplied from abroad, usually a pre-shipment inspection is done.

LGED has a predefined list of laboratory tests and frequency to be performed during execution of works corresponding to items of work in their schedule of rates. A customized list of test and frequency is appended in the tender document. So, contractors are aware in advance what test to be performed and they can also assess the cost of laboratory tests in order to incorporate these costs in their offered price as the cost related to laboratory tests to be borne by the contractor.

LGED has a central quality control laboratory. They also have 64 District Laboratories in all 64 districts. Usually, the district lab (DL) performs the tests required to verify the materials provided by the contractor comply with the specifications provided in design documents and the frequency prescribed in tender documents. Most of the tests are being conducted by the DL except a few tests such as steel testing. The rectification is ensured prior to making any running and/or final payment to the contractors.

Construction Monitoring Process

In any project, the Project Management Unit monitors the implementation process. LGED Sub-district & District Level officers directly supervise the implementation process. LGED Regional and Division Level Officers regularly visit and monitor the sites. Beyond these, there

are 20 (twenty) monitoring teams, each in one region, from LGED headquarters monitor and report to the Chief Engineer.

Implementation Monitoring and Evaluation Division (IMED) is a Bangladesh government division under the Ministry of Planning is also responsible for Monitoring and Evaluation of development projects under the Annual Development Program. They also carry out final evaluation at the end of the project. Besides, Members of Parliament and officials of the concerned ministry visit the sites randomly in order to resolve local conflicts and provide guidance if needed.

Construction As-built Documentation

The procedure is in place as per General or Particular Conditions of Contract (GCC/PCC); but in reality there is no set example of keeping such records.

Opportunities

- While the Procurement Process is clear and well defined, its implementation varies from project to project (significant deviation is observed in roads than bridges);
- The Construction industry seems to work below optimal conditions (consolidated contractor´s market) due to a) slow procurement process leading to construction cost increase and/or originated by incomplete design package, b) lack of construction supervision including material quality, and c) payment mechanisms;
- Non-compliant practices (Ad-hoc practice based on experience) of small roads contractors still exists;
- Compliance (Quality Assurance) of purchase materials;
- Financial/Cash payment availability through clear and planned budget mechanisms as an incentive measure to Constructors;
- Enhancement of the Quality Assurance and Quality Control onsite;

Recommendations

- To undertake a process for pre-approved Contractors and Engineering Firms to expedite the process of design and construction and create a competitive market;
- Technical Information Sessions with Contractors (share risk for a competitive market/price);
- To enforce Public Procurement Regulation (PPR) for Contractor's Quality Assurance compliance;
- Traceability of construction material (Origine, Quality Certificates, Clear Transport, Storage and Handling requirements and compliance to thoses); => Mitigation measure: a) Streamline mechanism of Design Change, b) conservative design by means of a) higher Factor of Safety or b) lower material Characteristic values);
- To strengthen local contractor capability on quality assurance process thru incentive measures;

- To promote Quality Assurance (LGED Auditing Department) Engineers to perform site visits for both, Quality Assurance and Training;
- To enhance Quality Assurance (LGED Auditing Department) thru check-lists, evaluation techniques and procedures (digitalization) that feeds back "Lesson Learnt" process;
- To digitalize "As Built" Technical Documentation;

7. OPERATION AND MAINTENANCE

Aim and Objectives

The aim of this section is to understand the operation and maintenance strategy, program and finance, to maintain the serviceability of the infrastructure and its design life.

This section´s objectives are a) to confirm maintenance regulation and operator´s compliance, b) to confirm KPIs monitoring indexes and/or performance service levels, c) public incentive programs, if any, and d) contingency/repair strategy processes.

Key findings

- Despite the different attempts, the allocation of financial resources to maintain the built infrastructures remained far below the needs;
- Lack of financial/budgetary mechanisms leading to a financial support to a) Operation and Maintenance Personnel, and b) Infrastructure life-time investment (Infrastructure Asset Value), resulting in a premature "aging" infrastructure;
- 50% of the LGED paved network have exceeded the maximum design life (10+years), resulting in accelerated deterioration rate;
- LGED does not have any formal mechanism to monitor the KPIs/Performance Service Level to evaluate their investment in maintenance work (Maintenance and Repair Works);
- The routine maintenance is mostly done by the labor contracting society (LCS) or the LGED mobile maintenance team (MMT); Routine maintenance is sometimes referred to as "reactive maintenance."

However

- Nationwide programs and guidelines are developed to account for the whole cycle of the maintenance activities including survey, planning, preparation, implementation and monitoring & evaluation. It also provides the directives in regards to administrative, technical and financial aspects.
- Asset Management Policy developed under the National Resilience Programme has recently been adopted for organizational internal usages at LGED.
- For roads, LGED has adequate competent manpower to execute the annual maintenance programme effectively and efficiently. However, for Bridge Inspection and Maintenance works,, LGED requires the support of professional training for optimum use of the equipment and repair procedures.

Compliance of Policy and Guideline

The government had started allocating more funds for rural infrastructure from the mid 1980's following the administrative decentralisation in the country. Until the early 1990's, there was no policy attention on how the rural infrastructures built across the country were to be maintained. As the pressures were built up to protect the investment on rural infrastructure, the government, in 1992-93, had made a provision of 'rural infrastructure maintenance fund' under its non-development budget. The new programme namely "Rural Roads and Culvert Maintenance Programme" started its journey with BDT 300 million, which now stands for BDT 46,850 million. Initially, the Programme was governed by a two pager instructions - mostly administrative instruction and financial management guidelines - which, later on, was transformed into a comprehensive guideline for implementation of the Programme. The new guidelines cover the whole cycle of the maintenance activities including survey, planning, preparation, implementation and monitoring & evaluation. It also provides the directives in regards to administrative, technical and financial aspects.

There has been a revolution of rural infrastructures across the country during 1990-2010, which played a key role in the socio-economic upliftment of Bangladesh. However, the allocation of financial resources to maintain the built infrastructures remained far below the requirement. The maintenance need and financing arrangements started falling apart more and more. This underfunding resulted in rapid deterioration of built infrastructure leading to adverse reactions in various quarters. In this backdrop, the Government approved 'Rural Road and Bridge Maintenance Policy' in 2013 that provides clear directives to deliver LGED maintenance programmes. The salient elements of the Policy include:

- Planning and Programming
- Prioritization of Rural Road Maintenance
- Environmental Considerations
- Road Safety
- Implementation Policy
- Stakeholders Participation
- Gender Equity and Development
- Financing Mobilization
    - GoB Fund under Revenue Head,
    - Development project share to Maintenance,
    - Development Project for Backlog Maintenance,
    - Local Government Institute (LGI) Financing,
    - Financing by Private Sector
- Vehicle Overloading Control
- Institutional Policy
- Manpower Development
- Research/ Study and Information Management

In order to ensure the operator's compliance, Asset Management Policy developed under the National Resilience Programme has recently been adopted for organizational internal usages. Subsequently, Strategic Asset Management Plan (SAMP) and Asset Management Plans (AMPs) are being developed under NRP.

Operation and Maintenance Plan

At present, LGED does not have any formal mechanism to monitor the KPIs/Performance Service Level to evaluate their investment in maintenance works. For benchmarking the agency's maintenance standards in keeping the rural road and bridge accessible, safe and reliable to the users, there is a need to establish a key performance target which may change over time. Given the reality and user perception of the level of service (LOS), different performance targets can be set in accordance with road class or traffic volume.

The routine maintenance is mostly done by the Labor Contracting Society (LCS) or the LGED mobile maintenance team (MMT). Routine maintenance is sometimes referred to as "reactive maintenance." This suggests that it is work that is performed as a reaction to a specific distress such as patching, edge repairs, vegetation control, shoulder grading, clearing site drains etc.

On average, the routine maintenance accounts for 5% of the total budget allocation. The Executive Engineer at district level has procured the materials for mobile maintenance works and they organized a team consisting of 5 members including vehicle drivers. The team is sent to different upazilas upon request of Upazila Engineers to restore small patches. Repairing of periodic maintenance and rehabilitation type works are done by the contractor. Verges and slopes are maintained by LCS. LCS team usually consists of destitute women. Size of the team depends on the length of the road. One woman is engaged for one km length of road. They are paid on a monthly basis.

Historically, allocation of funds for road maintenance have never been sufficient to cover all the requirements to keep the road in good to fair condition. Despite an increase in the share of GoB revenue budget from BDT 300 million (c. 3.5 million US$) in 1992-1993 to BDT 46,850 million (c. 550 million US$) in 2019-2020 for the purpose of rural road maintenance, funding still lags significantly once inflation factor is taken into account. There was a shortfall of approximately BDT 16,220 million (c. 200 million US$) during the 2019-2020 fiscal year. As an order of magnitude, the required Inspection and Maintenance seems to be in the order of [BDT 46,850 million (c. 550 million US$) + BDT 16,220 million (c. 200 million US$)] / 353,140 km of rural roads = BDT 0.178 million/km = BDT 178 /m (c. 2 US$/m);

As mentioned earlier, and an additional constraint to the Inspection and Maintenance work of LGED´s Infrastructures, Bangladesh's road sector heavily depends on very limited sources of localized quarries (gravel from Punchagarh, Jhenaigati, Jaflong and Bholagonj) and the sand from the river bank or the import of road construction materials (either as raw material or finished goods). These limited sources often hinder the quality maintenance in the field.

LGED collects both IRI and the detailed condition data to quantify how the paved network is performing. However, IRI data is used to identify the road performance level.

Qualifications of Professionals

Out of total 116,000 km of paved road (2019 inventory), more than 50% of the LGED paved network have exceeded the maximum design life (10+years), resulting in an aging network with little and no effect on maintenance activities. A dynamic multi-year forwarding programme requires to have the analytical capabilities to quantify the rate of pavement deterioration over the plan years as well as forecasting the funding requirements given the choices of maintenance strategies. The Road and Structure Database Management System (RSDMS) maintained by the LGED does not have this capability. Therefore, development of such forwarding programmes should be prioritized.

LGED has adequate competent manpower to execute the annual maintenance programme effectively and efficiently. The tasks from scheme preparation to contract management are done by LGED's own staff. They do not need to engage consultants even for collection and organize the condition of roads. Technical knowhow of LGED engineers about the operation of road maintenance works is an advanced level compared to bridge maintenance works. They need professional training on bridge maintenance in terms of selection of appropriate maintenance treatment and optimum use of the equipment to assess the condition and execute the repair works.

Opportunities

- Under the National Resilience Programme, to define a legal framework for Inspection/maintenance works that would lead to a) the definition in subsequent stages of personnels´ roles and responsibilities and b) financial and budgetary mechanism for Inspection and Maintenance/Repair;
- Similarly, under the National Resilience Programme, the development of the Asset Management Policy and Plan at LGED level (ongoing);
- Development of sensibilization campaign in the importance of inspection and maintenance of roads and bridges infrastructures;
- Continuous engagement of the LCS entities by means of "on the job" training programs;

Recommendations

- As indicated earlier, to amend current work on Strategic Asset Management and corresponding Asset Management Plan with an additional level "Level 6 / Observations / Weakness Sign (WS)";
- To develop Inspection and Maintenance Continuous Training programs (continuous learning, homogeneous assessment and procedure, lesson learnt, …);
- To digitalize Inspection and Maintenance Processes, including Planning/Site Visit Processes;
- To streamline LGED capacity for road and bridge Inspection & Maintenance (I&M) Personnel (Manpower and to shift from "reactive" to "prevention" actions), including the possibility to subcontract some of the services in remote locations and/or for routine inspection works;
- To define non-subjective criteria for "unlocking" Emergency budget as part of the Contingency Plan;

8. CONCLUSIONS

The aim of this work is to undertake a rapid national-level diagnosis (desk study) on LGED´s asset and performance in order to get an informed understanding of the vulnerability of rural road and bridge infrastructure networks in Bangladesh and contributing factors of risk. Certainly, this report could have been more extensive and detailed on some of the chapters, but has reached a good level to understand LGED´s Asset status and Major Failure Modes in roads and bridges to allow the beginning of Stage 2 "Failure Analysis Report and Tool Kit" including Training Material Course.

The success of Stage 2 relies essentially in LGED commitment to this failure analysis study. Without LGED leadership commitment and input, the success of this work will be limited and will remain academical. A collaborative work is required and shall be engaged sooner than later, which may require some thinking shifting from all stakeholders.

"Only with an open-minded strategy, with a common goal (resilient infrastructure design for our society), significant improvement in infrastructure quality assurance will be obtained."