

**FY2020 Study on Business Opportunity of
High-quality Infrastructure to Overseas**

Railway Modernization Project in Turkmenistan

Final Report

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Prepared by:

Oriental Consultants Global Co., Ltd.

Preface

We, Oriental Consultants Global Co., Ltd. were given in trust by the Ministry of Economy, Trade, and Industry of Japan (METI) and conducted the study on “Railway Modernization Project in Turkmenistan” as a part of the Study on Business Opportunity of High-quality Infrastructure to Overseas for the FY2020. The outcomes of the study are summarized in this report.

The study, “Railway Modernization Project in Turkmenistan,” aimed at understanding the current state and issues of the national railway sector in the target section of the 1,176 km east-west corridor (from Turkmenbasy to Turkmenabat via Ashgabat). The main components of the study are gathering the information on the current status of existing routes, collecting the information in connection to modernization plan focused on electrification, study on financing options for the project, and cooperation of the Japanese side related to the project in the future.

We hope this report will help to the realization of the project, and will provide useful information to Japanese stakeholders.

February 2020

Oriental Consultants Global Co., Ltd

Table of Contents

1. Outline of the Study	1-1
1.1 Background and Purpose of the Study	1-1
1.2 Scopes of the Study	1-1
1.3 Study Schedule	1-3
1.4 Composition of the Study Team	1-3
1.5 Counterparts of the Study	1-4
2. Overview of Turkmenistan	2-1
2.1 About Turkmenistan	2-1
2.2 Population	2-1
2.3 GDP	2-1
2.4 Consumer Price Index	2-2
2.5 Power Supply Situation	2-3
2.5.1 Power Transmission Line Network	2-4
2.5.2 Supply and Demand	2-4
2.6 Overview of the Natural Environment	2-5
3. Present Situation of Railway Sector and Study Section	3-1
3.1 Route Map	3-1
3.2 Organization Chart	3-1
3.3 Overview of Cargo and Passenger Demand	3-2
3.3.1 Cargo Transportation	3-2
3.3.2 Passenger Transportation	3-5
3.4 Operation Status	3-6
3.5 Civil Structures	3-7
3.5.1 Construction Gauge	3-7
3.5.2 Roadbed and Track	3-8
3.5.3 Bridge and Drainage Culvert	3-15
3.5.4 Overbridge	3-17
3.5.5 Level Crossing	3-19
3.6 Cargo Station and Passenger Station	3-19
3.6.1 Cargo Station	3-19
3.6.2 Passenger Station	3-21
3.7 Signal and Telecommunication	3-22
3.7.1 Signal	3-23
3.7.2 Telecommunication	3-24
3.8 Rolling Stock, Depot and Workshop	3-24

3.8.1	Rolling Stock	3-24
3.8.2	Inspection Type and its frequency	3-25
3.8.3	Depot and Workshop	3-26
4.	Formulation of the Basic Plan	4-1
4.1	Review of Relevant Plans.....	4-1
4.2	Future Demand Forecast.....	4-1
4.2.1	Introduction	4-1
4.2.2	Assumptions for Future Demand Analysis	4-2
4.2.3	Result of Cargo and Passenger Demand Forecast	4-6
4.2.4	Train Operation	4-10
4.3	Overview of Alternatives for Modernization.....	4-11
4.3.2	Items of the Alternative Options	4-12
4.3.3	Comparison of Alternatives.....	4-16
4.3.4	Staged Development Plan	4-20
4.4	First Stage of Modernization Plan	4-21
4.4.1	Operation Plan.....	4-22
4.4.2	Plan for Civil Structures	4-26
4.4.3	Plan for Train Station Facilities	4-39
4.4.4	Plan for Electrical System.....	4-39
4.4.5	Plan for Signal and Telecommunication.....	4-51
4.4.6	Plan for Rolling Stocks.....	4-53
4.4.7	Plan for Depots and Workshops	4-55
4.4.8	Project Cost Estimation	4-59
4.4.9	Management Plan	4-59
4.4.10	Economic and Financial Analysis	4-60
5.	Evaluation of Environmental and Social Impacts	5-1
5.1	Current Situation of Environmental and Social Aspects	5-1
5.1.1	Natural Environment.....	5-1
5.1.2	Social Environment.....	5-2
5.2	Environmental Improvement Effects of Project Implementation	5-4
5.3	Environmental and Social Impacts of Project Implementation	5-4
5.4	Summary of Laws and Regulations Related to Environmental and Social Considerations in the Host Country	5-9
5.4.1	Summary of Laws and Regulations Related to Environmental and Social Considerations	5-9
5.4.2	National Standard of Turkmenistan for Environmental Impact Assessment on the proposed economic and other activities (2001).....	5-10
5.4.3	Land Acquisition	5-12
5.5	Necessary Actions by the Host Country for Project Implementation	5-12

6.	Outlook for Operation Plan and Project Financing	6-1
6.1	Implementation Scheme	6-1
6.2	Possible Contract Packages	6-2
7.	Project Implementation Schedule	7-1
8.	The Advantages of Japanese Companies	8-1
8.1	Rolling Stocks (Electric Locomotives and EMU)	8-1
8.2	Equipment of Receiving Substation	8-1
8.3	Signalling.....	8-2
8.4	Equipment for Depot / Workshop	8-2
9.	Issues and Action Plans for Realization	9-1
9.1	Comprehensive and Detailed Technical Study and Preparation for Financing	9-1
9.2	Financing.....	9-2
9.3	Improvement of Financial Condition of the RA.....	9-2
9.4	Technical Discussion with Related Organizations.....	9-2
9.5	Establishment of Maintenance system (Rolling Stocks and Tracks)	9-3
9.6	Revision of Technical Standards	9-3

List of Figures and Tables

Figure 2-1 Population and Population Growth Rate.....	2-1
Figure 2-2 Constant GDP and Constant GDP Growth Rate	2-2
Figure 2-3 Sector wise GDP in Current Price	2-2
Figure 2-4 Consumer Price Index (CPI).....	2-3
Figure 2-5 Power Plants and Major Power Transmission Lines in Turkmenistan.....	2-4
Figure 2-6 Climate Classification of Turkmenistan	2-5
Figure 2-7 Precipitation and Average Temperature in Ashgabat	2-5
Figure 2-8 Major Earthquake Occurrence Points around Turkmenistan, M6.0 or higher	2-6
Figure 2-9 Major Locations of Active Faults around Turkmenistan	2-6
Figure 3-1 Map of the Study Route.....	3-1
Figure 3-2 Organization Chart of the Railway Agency of Turkmenistan.....	3-2
Figure 3-3 Cargo Handling Volume from 2015 to 2018.....	3-3
Figure 3-4 Monthly Fluctuation of Cargo Transportation in 2018.....	3-3
Figure 3-5 Cargo Handling Volume by Product Type in 2018	3-4
Figure 3-6 Number of Passenger Transported by Railway (2015 - 2019).....	3-5
Figure 3-7 Daily No. of Train by Section in 2019.....	3-6
Figure 3-8 Construction Gauge for Non-Electrified Section.....	3-8
Figure 3-9 Standard Cross Section.....	3-9
Figure 3-10 Roadbed Mud-pumping	3-10
Figure 3-11 Lack of Ballast.....	3-11
Figure 3-12 Ballast Quarry Location Map	3-12
Figure 3-13 Damaged Sleeper.....	3-12
Figure 3-14 Continuous Welded Rail in Turkmenistan	3-13
Figure 3-15 Damaged Rail-end	3-13
Figure 3-16 Superstructure Type	3-15
Figure 3-17 Horizontal Reinforcement Bar for the Steel through Truss Girder.....	3-16
Figure 3-18 Clearance of Steel through Truss Bridge over the Amu Darya River (Reference)	3-16
Figure 3-19 Drainage Culvert.....	3-17
Figure 3-20 Clearance under the Overpass near Ashgabat Station.....	3-18
Figure 3-21 Clearance under the Pedestrian Bridge at Ashgabat Station.....	3-19
Figure 3-22 Level Crossing.....	3-19
Figure 3-23 Turkmenbasy Cargo Station.....	3-21
Figure 3-24 Passenger Station	3-22
Figure 3-25 Passenger Station Platform	3-22
Figure 3-26 Most Common Locomotives using in Turkmenistan.....	3-25
Figure 4-1 Future Population Forecast of Turkmenistan.....	4-3

Figure 4-2 Forecast of Future Cargo Volume Uusing Different Scenarios.....	4-5
Figure 4-3 Product Wise Non-transit Cargo Demand of 2025 from Turkmenbasy to Turkmenabat	4-7
Figure 4-4 Product Wise Non-transit Cargo Demand of 2025 from Turkmenabat to Turkmenbasy	4-7
Figure 4-5 Product Wise Transit Cargo Demand of 2025 from Turkmenbasy to Turkmenabat	4-8
Figure 4-6 Product Wise Transit Cargo Demand of 2025 from Turkmenabat to Turkmenbasy	4-8
Figure 4-7 Required Number of Trains in 2040 from Turkmenbasy to Turkmenabat.....	4-10
Figure 4-8 Required Number of Trains in 2055 from Turkmenbasy to Turkmenabat.....	4-11
Figure 4-9 Flow of Alternative Selection	4-11
Figure 4-10 Target Section of Geokdepe – Ashgabat – Anew.....	4-15
Figure 4-11 Target Section of Garybata – Mary – Bayramaly.....	4-15
Figure 4-12 Comparison Items for Alternative Selection.....	4-16
Figure 4-13 Considered of Divided Sections for the Study Route	4-21
Figure 4-14 First-Stage Modernization Plan	4-22
Figure 4-15 Required Number of Trains in the Target Section in 2040	4-24
Figure 4-16 Required Number of Trains in the Target Section in 2055	4-25
Figure 4-17 Flow for Selection of Mud-Pumping Countermeasures	4-27
Figure 4-18 Multiple Tie Tamper (MTT)	4-28
Figure 4-19 Current Rail Bond in Turkmenistan.....	4-29
Figure 4-20 Mesh Fence.....	4-29
Figure 4-21 Temporary Access Road	4-30
Figure 4-22 Structure Width of New Single-Bridge for Double Track (Tentative).....	4-31
Figure 4-23 New Embankment for Double Track	4-31
Figure 4-24 Construction Gauge for Electrification considered within Turkmenistan Railway Agency	4-33
Figure 4-25 Minimum Construction Gauge for Railway Tunnel connecting China, Kyrgyzstan and Uzbekistan	4-35
Figure 4-26 Construction Gauge for Electrification with Minimum Construction Gauge for Bridges and Tunnels (Tentative).....	4-36
Figure 4-27 Joint Structure for Continuous Welded Rail in Japan	4-38
Figure 4-28 Substation Plan Considering Connecting Transmission Lines (between Turkmenbasy and Ashgabad).....	4-41
Figure 4-29 Substation Plan Considering Connecting Transmission Lines (between Ashgabad and Turkmenabat).....	4-42
Figure 4-30 Current Air Braking Device.....	4-54
Figure 4-31 Overhead Catenary Line	4-56
Figure 4-32 Pantograph	4-57
Figure 4-33 Proposed Management Organization Chart	4-60
Figure 5-1 Geology of Turkmenistan	5-1
Figure 5-2 Map of Conservation Areas in Turkmenistan	5-2

Figure 5-3 Land Use along the Railway Section of Target Route	5-3
Figure 5-4 Organization Chart of MoAEP	5-12
Figure 6-1 Project Implementation Scheme	6-1
Figure 6-2 Example of Contract Package (Case 1)	6-2
Figure 6-3 Example of Contract Package (Case 2)	6-3
Figure 6-4 Example of Contract Package (Case 3)	6-4
Figure 7-1 Project Implementation Schedule	7-2
Table 1-1 Field Survey Schedule.....	1-3
Table 1-2 Composition of the Study Team	1-3
Table 1-3 Study Related Organizations/Companies	1-4
Table 2-1 Major Earthquakes around Turkmenistan (M6.0 or higher)	2-7
Table 3-1 Cargo Handling Volume by Product Type in 2018 (Unit thousand Ton).....	3-5
Table 3-2 Specifications for Current Track Structure and Track Alignment (Turkmenabat - Turkmenbasy)....	3-10
Table 3-3 Number of Turnout Location between Major Stations	3-14
Table 3-4 Curve Radius of the Alignment between Turkmenabat - Turkmenbasy	3-14
Table 3-5 Gradient between Turkmenbat - Ashgabat - Turkmenbasy	3-14
Table 3-6 Number of Locomotives under the RA	3-24
Table 3-7 Inspection Type and its Frequency	3-25
Table 3-8 Rolling Stock Type for each Depot/Workshop	3-26
Table 4-1 Future Total GDP of Turkmenistan and Neighbouring Countries (2010 constant), billion USD	4-3
Table 4-2 Growth Rate Calculation using Elasticity Value	4-4
Table 4-3 List of the Factories Constructed by the Japanese Companies.....	4-6
Table 4-4 Cargo Demand Forecast between Turkmenbasy and Turkmenabat ('000 Ton/year).....	4-9
Table 4-5 Future Passenger Demand Forecast between Turkmenbasy and Turkmenabat ('000 pax)	4-10
Table 4-6 Items of Improvements.....	4-12
Table 4-7 Alternatives of Modernization.....	4-12
Table 4-8 Score and Description of Capacity	4-16
Table 4-9 Score and Description of Speed	4-17
Table 4-10 Items for Impact on Railway Operation	4-17
Table 4-11 Score and Description for Impact on Railway Operation.....	4-18
Table 4-12 Estimated Cost of Each Alternative.....	4-19
Table 4-13 Score and Description for Cost.....	4-19
Table 4-14 Score and Description for Environmental and Social Impact	4-20
Table 4-15 Overall Evaluation of the Alternatives	4-20
Table 4-16 Required Number of Electric Locomotive in the Target Section for First Stage Modernization.....	4-24
Table 4-17 Speed in Curve and Curve Radius (Reference)	4-32
Table 4-18 Train Line Voltage	4-43

Table 4-19 load-compensating device of vehicles.....	4-53
Table 4-20 Considered Electric Locomotive Specifications.....	4-54
Table 4-21 Considered EMU Specifications	4-55
Table 4-22 Number of Rolling Stocks Required for First-stage Modernization	4-55
Table 4-23 Structural Features of Diesel and Electric Locomotives (only Important Parts).....	4-55
Table 4-24 Estimated Project Cost of the First Stage	4-59
Table 4-25 Economic Benefits	4-62
Table 4-26 Economic Cost	4-63
Table 4-27 Cost Benefit Analysis Results	4-63
Table 4-28 Income from Revenue Income	4-64
Table 4-29 Cost	4-65
Table 4-30 Result of Cash Flow Analysis	4-65
Table 4-31 Sensitivity Analysis of FIRR (changes due to government subsidies)	4-65
Table 4-32 Sensitivity Analysis of FIRR (changes due to government subsidies and the effect of 20% increase in freight revenues).....	4-66
Table 5-1 List of Conservation Areas in Turkmenistan	5-2
Table 5-2 Population composition ratio in Turkmenistan.....	5-3
Table 5-3 Scoping Matrix	5-5
Table 5-4 Scoping result.....	5-6
Table 5-5 Main Environmental and Social Laws and Regulations in Turkmenistan.....	5-10
Table 5-6 List of Environmentally Hazardous types of Economic and Other Activities.....	5-11

List of Abbreviations

No.	Abbreviation	English
1	ADB	Asian Development Bank
2	ATS	Automatic Train Stop
3	CAREC	Central Asia Regional Economic Cooperation Program
4	CWR	Continuous Welded Rail
5	DEMU	Diesel-Electric Multiple Unit
6	DF/R	Draft Final Report
7	DMU	Diesel Multiple Unit
8	ECAs	Export Credit Agencies
9	ECO	Economic Cooperation Organization
10	EMU	Electric Multiple Unit
11	EU	European Union
12	F/R	Final Report
13	F/S	Feasibility Study
14	GDP	Gross Domestic Product
15	IMF	International Monetary Fund
16	IsDB	Islamic Development Bank
17	JBIC	Japan Bank for International Cooperation
18	JICA	Japan International Cooperation Agency
19	MTT	Multiple Tie Tamper
20	NPV	Net Present Value
21	RA	Railway Agency of Turkmenistan
22	ROW	Right of Way
23	SEA	Strategic Environmental Assessment
24	Turk Exim Bank	Export Credit Bank of Turkey
25	WB	World Bank
26	JPY	Japanese Yen
27	TRM	Turkmenistan Manat
28	USD	United States Dollar

1. Outline of the Study

1.1 Background and Purpose of the Study

Turkmenistan is a quasi-landlocked country located in the centre of Central Asia and the railway network is very important for international transport with neighbouring countries. However, the railways constructed during the Soviet Union and the Russian Empire are aging, and the current average operating speed is limited to 30 - 50 km/h, which is inefficient. If the railway is modernized, demand is expected to increase, and a major economic impact is expected by improving the efficiency of railway transportation. The Government of Turkmenistan has also recognized that the modernization of railways is indispensable for the expansion of industrial development in the future. Thus in 2018, the Government of Turkmenistan has requested support from the Ministry of Economy, Trade and Industry for railway electrification projects, having high expectations for Japanese high-quality railway technology and services.

This study is a feasibility study on the modernization of railways mainly on electrification of existing lines in Turkmenistan, where the target section of the 1,176 km east-west corridor Turkmenabat - Ashgabat - Turkmenbasy was selected for the following purposes: “A. Understanding the current state and issues of the railway sector in Turkmenistan”, “B. Gathering information for the railway modernization project centring on electrification” and “C. Studying the Japanese side's cooperation system and financing for the railway modernization project centring on electrification”.

1.2 Scopes of the Study

The following items were surveyed and examined for the target section of the 1,176 km east-west corridor Turkmenabat - Ashgabat - Turkmenbasy.

1. Understanding the present situation and issues of the railway sector in Turkmenistan
 - Understanding the current status of the railway sector (organizational structure, railway facilities and equipment, rolling stocks, train operation, freight traffic, etc.).
 - Confirmation of development plan of railway sector and positioning of railway modernization plan centering on railway electrification.
 - Understanding issues in the railway sector (aged track, inefficient operation, aging of engineers, etc.).
2. Information collection, investigation, and analysis for railway modernization
 - Collecting and organizing information on the current status and future forecast of freight transportation, and implementing simple demand forecasting.

- Conduct technical studies on railway systems (tracks, electric power, overhead lines, signal and communication, locomotives, wagons, train depots, maintenance facilities, etc.) for modernization of railways centering on electrification.
 - Analyse the feasibility and consistency of Japanese technology on the specifications of electrification, locomotives and signal communication systems, taking into account the current and future plans of Uzbekistan's railway system to which the lines are connected.
 - Create and analyse a train operation transportation plan based on the estimated cargo transportation volume.
 - Conduct an initial environmental survey for the modernization of railways, mainly for electrification.
 - Collect and organize information on unit prices of procured equipment required for project cost estimation.
 - Collect and organize information related to economic evaluation and implement economic evaluation based on demand forecast.
3. Basic plan of railway system
- Based on the information and survey/analysis results of the railway system obtained in (2), prepare a rough maintenance plan of the railway system and a plan for improving the railway system, and arrange the procured equipment.
 - In particular, for rolling stocks, signal/communication systems, and substations, consider the introduction of Japanese technology.
4. Cost estimation, etc.
- Estimate cost based on the basic plan of the railway system obtained in (3).
 - Consultation with the Government of Turkmenistan and related organizations on the estimated cost.
5. Project implementation scheme, implementation schedule
- Establish a project implementation scheme, discuss the project implementation scheme with the Government of Turkmenistan and related organizations, etc., and consider the schedule for future project implementation.
6. Consideration and proposal of finance
- After considering and organizing funding schemes by Japanese organizations and international organizations such as the Asian Development Bank (ADB), consultation with the Government of Turkmenistan and related organizations.

7. Confirming the advantages of Japanese companies and measures to strengthen them

- When Japanese companies participate in the business, consider measures to strengthen the cost competitiveness that should be taken while exhibiting the strengths of Japanese companies.
- Examination of the possibility of cooperation with third country companies.

1.3 Study Schedule

This study was conducted from August 2019 to the end of February 2020. As shown in the table below, four field surveys were conducted.

Table 1-1 Field Survey Schedule

	Survey period	Survey location
Survey 1	From August 17 to September 1, 2019	Ashgabat, Turkmenbasy, Mary, Turkmenabat, Tashkent
Survey 2	From November 3 to November 14, 2019	Ashgabat
Survey 3	From December 16 to December 25, 2019	Ashgabat, Gypjak, Bereket, Turkmenbasy, Istanbul
Survey 4	From January 16 to January 26, 2020	Ashgabat

Source: Study Team

1.4 Composition of the Study Team

The following table shows the names, duties, and affiliations of the members of the Study Team.

Table 1-2 Composition of the Study Team

Name	Assigned duties	Affiliation
Hirohisa Kawaguchi	Team Leader / Railway Planning	Oriental Consultants Global Co., Ltd.
Kazumasa Yamaoka	Deputy Team Leader /Railway Infrastructures 1	Oriental Consultants Global Co., Ltd.
Nobuyoshi Kawai	Railway Infrastructures 2	Oriental Consultants Global Co., Ltd.
Hiroyuki Aizawa	Railway Civil Structures	Oriental Consultants Global Co., Ltd.
Toshimi Kaneko	Electricity Planning	Oriental Consultants Global Co., Ltd.
Kunihiko Higuchi	Signal and Telecommunication	Oriental Consultants Global Co., Ltd.
Katsuo Funaki	Rolling Stock Planning	Japan Freight Railway Company
Kenji Oyama	Operation Planning	Japan Freight Railway Company
Szu-Chia Huang	Cost Estimation	Oriental Consultants Global Co., Ltd.
Pallab Debnath	Demand Forecast 1	Oriental Consultants Global Co., Ltd.
Naoki Murayama	Demand Forecast 2	Oriental Consultants Global Co., Ltd.
Kumi Okayama	Economic and Financial Analysis / Fund Planning	Oriental Consultants Global Co., Ltd.
Keigo Ando	Environmental and Social Considerations	Oriental Consultants Global Co., Ltd.

Source: Study Team

1.5 Counterparts of the Study

In this study, interviews were conducted with the related organizations shown in the table below.

Table 1-3 Study Related Organizations/Companies

	Institution name
Government of Turkmenistan	Railway Transportation Agency (Construction Bureau, Transportation and Logistics Bureau, Track Maintenance Bureau, Economic and Financing Bureau, Design and Research Laboratory)
	Ministry of Agriculture and Environment
	Ministry of Finance and Economy
	Automobile Transportation Agency
	National Customs Agency
	National Statistical Commission
	Turkmenbasy International Seaport
	Turkmenistan Logistics Business Association
	TULM (Railway Logistics Corporation)
Uzbekistan Government Agency	Uzbekistan Railways
Embassy of Japan	Embassy of Japan in Turkmenistan
International Financial Institutions	Asian Development Bank
	Export Credit Bank of Turkey
Turkmenistan Private Companies	Great Silk Road (a logistics company)
	Dovrebap Ulag Merkezi (logistics operator)
	Kuwwatly Yollar (logistics operator)
	THT (transport company)
	Ynamly Kepil (EIA implementation company)
Turkish Private Companies	Ronesans Holding (construction company)
	IC ICTAS Construction (construction company)
	Nurol Construction (construction company)
	Yapi Merkezi (construction company)
	YEO Electrical Automation Inc. (Electrical construction company)
Japanese Companies	Itochu Corporation and Itochu Plantech Inc.
	Toshiba Infrastructure Systems & Solutions Corporation

Source: Study Team

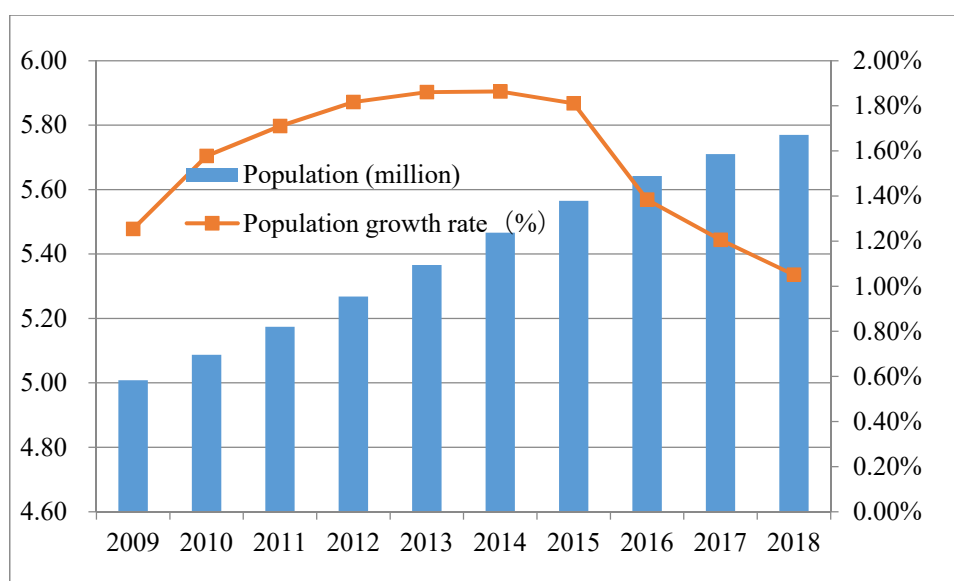
2. Overview of Turkmenistan

2.1 About Turkmenistan

Turkmenistan is located in the South-West part of Central Asia, bordering with Uzbekistan in the North-East, Kazakhstan in the North-West, Afghanistan in the South-East, Iran in the South-West and the Caspian Sea in the West. The land area is 491.21 square kilometres, which is about 1.3 times of Japan. However, about 85% of the country is covered by deserts. The country is consisted of five provinces, named as, Ahal, Balkan, Daşoguz, Lebap and Mary. The capital is called ‘Ashgabat’ located in Ahal Province.

2.2 Population

In 2018, the population of Turkmenistan was 5.77 million, the population density was 11.8 people/km², and the average annual population growth rate in the last 10 years (2009-2018) was 1.6%. Since then, the rate of population growth has declined somewhat, but has been growing at a rate of 1.0% or more.

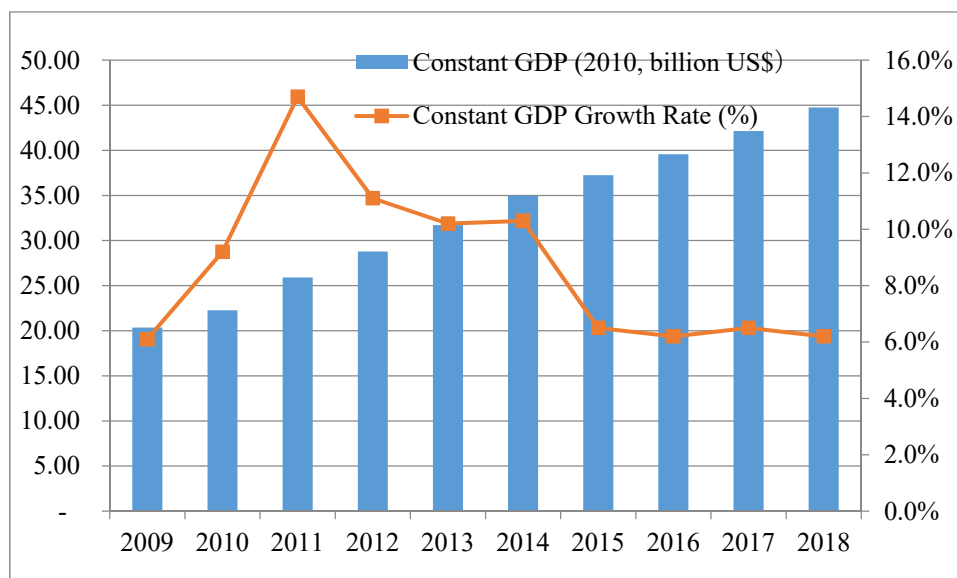


Source: IMF

Figure 2-1 Population and Population Growth Rate

2.3 GDP

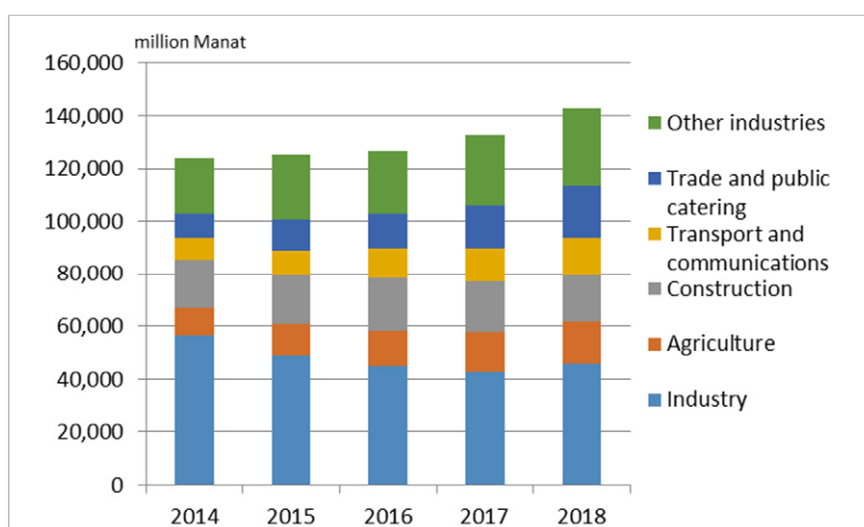
Turkmenistan's constant GDP in 2018 was USD 44.7 billion, with an average GDP growth rate of 8.7% over the past 10 years. Since 2015, the country has maintained a stable constant GDP growth rate in the 6% range and the GDP per capita in 2018 was USD 7,646.



Source: IMF

Figure 2-2 Constant GDP and Constant GDP Growth Rate

Looking at GDP by sector in 2018, industries account for 32%, agriculture 11%, construction 13%, transportation and communications 10%, trade and public services 14%, and other industries 21%.

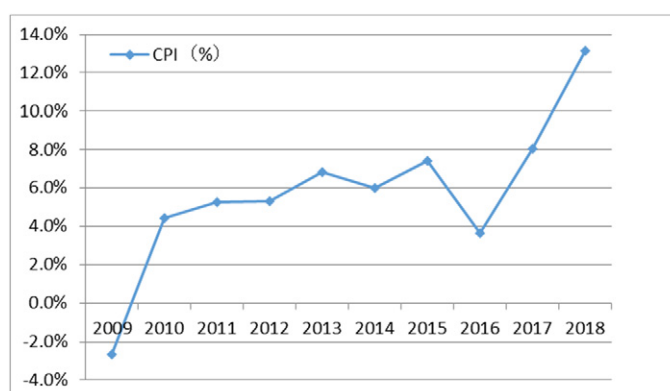


Source: Statistical Yearbook of Turkmenistan 2018

Figure 2-3 Sector wise GDP in Current Price

2.4 Consumer Price Index

The Consumer Price Index (CPI) in Turkmenistan has been growing since 2009, reaching 13.2% in 2018. According to the IMF, it is estimated that growth will be as high as 13% for several years after 2019.



Source: IMF

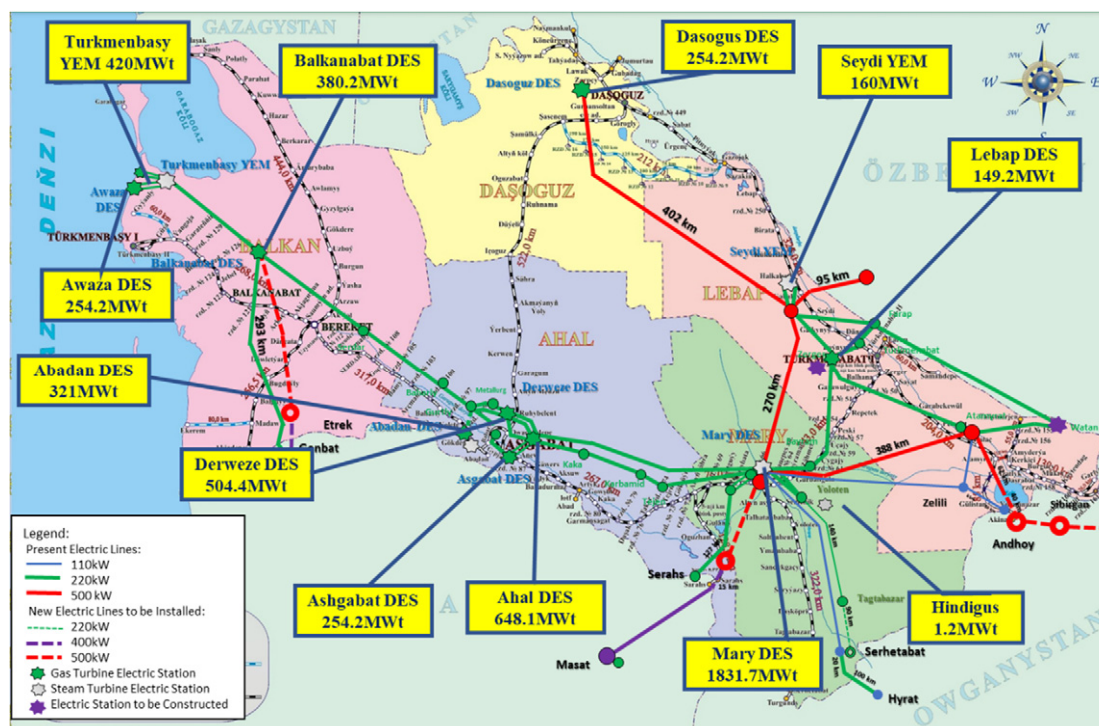
Figure 2-4 Consumer Price Index (CPI)

2.5 Power Supply Situation

Regarding the situation with electricity in Turkmenistan, the Government has built 5 gas turbine electric power stations in addition to the existing 25 power plants and has begun construction of a large power transmission network, substations, etc. As a result, the volume of electricity production has significantly increased and the export of electricity is a priority issue. Mainly exports are made to Afghanistan, Iran and Turkey, and there are high expectations from power transmission network projects with Uzbekistan, Tajikistan, and Pakistan.

Also, due to the development of the economy, the standard of residents' life is expected to increase. Currently, 14 steam turbine generators and 30 gas turbine devices are operated in 12 power plants. The following is a list of turbine generators of power plants:

- Power plant in Mary – 7 steam turbines and 3 gas turbines
- Power plant in Abadan-2 gas turbines
- Power plant in Turkmenbasy -2 steam turbines
- Power plant in the Seydi -2 steam turbine
- Power plant in Akhal – 7 gas turbines
- Power plant in Ashgabat-2 gas turbines
- Power plant in Dervaz – 4 gas turbines
- Power plant in Avaza– 2 gas turbines
- Power station in Balkanabad – 5 gas turbines
- Power plant in Dashoguz – 2 gas turbines
- Power plant in Lebap – 3 gas turbines
- Hydroelectric power plant in Gendygush, operating 3 hydro turbines, that were built in 1913



Source: Study Team (based on the data from The Institute of Energy Economics, Japan)

Figure 2-5 Power Plants and Major Power Transmission Lines in Turkmenistan

2.5.1 Power Transmission Line Network

The voltage of the Turkmenenergo power transmission lines is divided into-500kV and 220kV -which is called extra-high voltage in Japan, and 110 kV, 35 kV, 10 kV - which is called a special high voltage in Japan. Power plants in Turkmenbasy and Avaza are interconnected with 220kV power transmission lines. These power transmission lines are connected to the power plant in Balkanabat, and, it is connected to the direction of the power plant in Abadan with branch lines to Gonbad in Iran.

The power plants in Abadan, Dervaza, Ahal and Ashgabat make up the ring power transmission line surrounding Ashgabat city. In addition, the power transmission lines branch out from the power plant in Ahal into 2 and reach the power plant in Mary. The power plant in Mary has a huge capacity of 1,831.7 MW, which is connected with 500kV, 220 kV and 110 kV transmission lines. The power transmission line of 500 kV from the power plant in Mary is connected to the power plant in Seydi and Dashoguz. Also, the export to Hyrat and Andhoy of Afghanistan is carried out using strengthened 110 kV transmission lines. In addition, 220 kV transmission line network has been built through the Lebab power plant towards Turkmenabat.

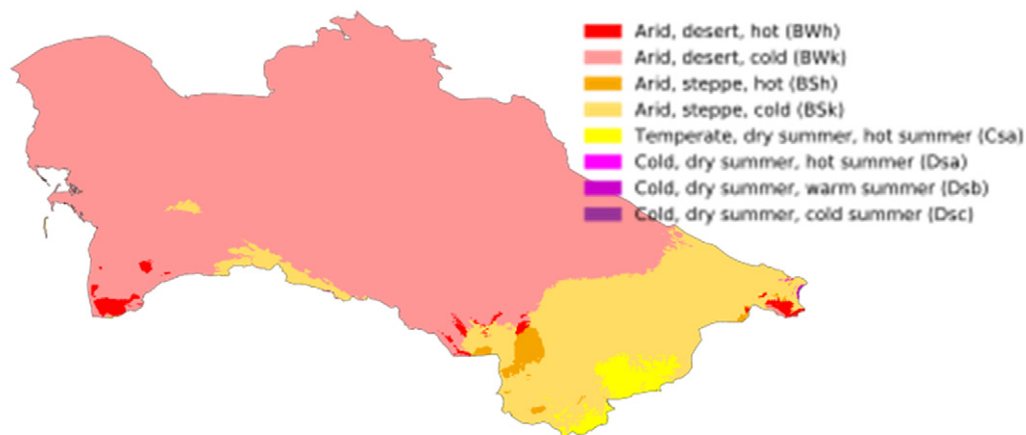
2.5.2 Supply and Demand

Regarding the situation in the past and the prospects for supply and demand, the volume of electricity production has increased significantly in comparison with the previous volumes. In addition, it is possible

to export electricity by expanding the transmission line network to neighbouring countries.

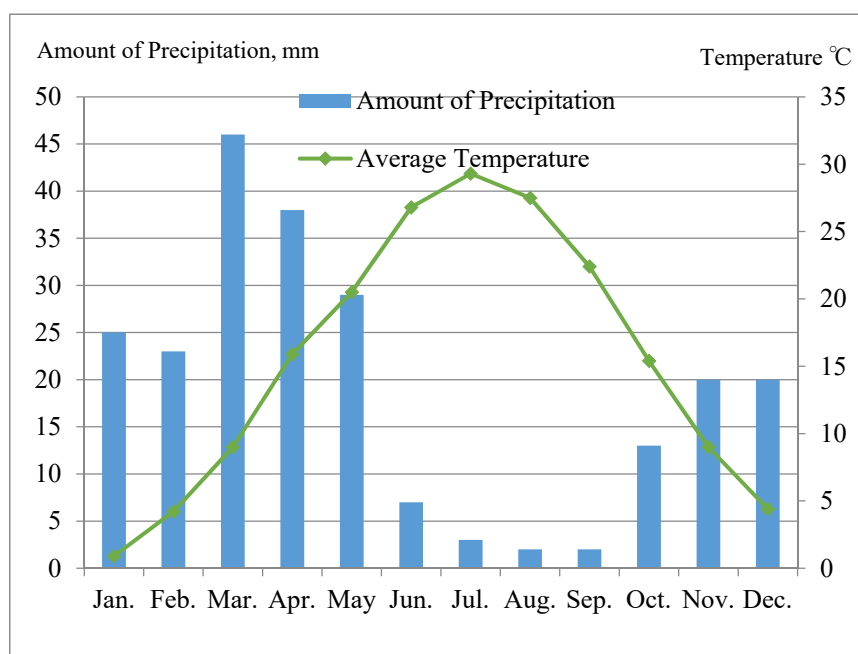
2.6 Overview of the Natural Environment

The Karakum Desert occupies 85% of the area and the country belongs to desert and steppe climates. The average annual rainfall is only 109 mm, which is very small, and the temperature varies greatly. The annual rainfall in Ashgabat is 228 mm and the average annual temperature is 15.4 °C.



Source: topographic-map.com

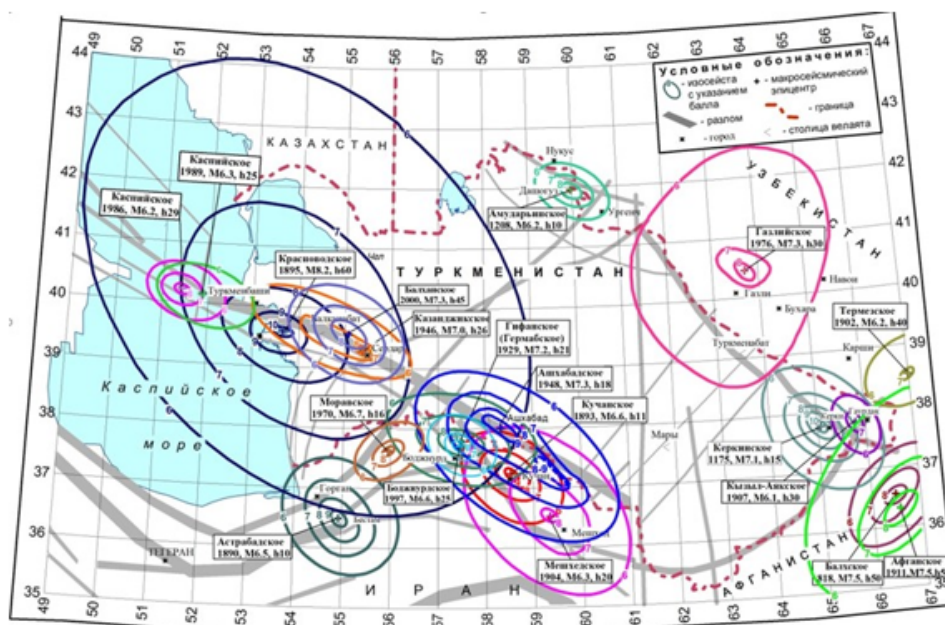
Figure 2-6 Climate Classification of Turkmenistan



Source: topographic-map.com

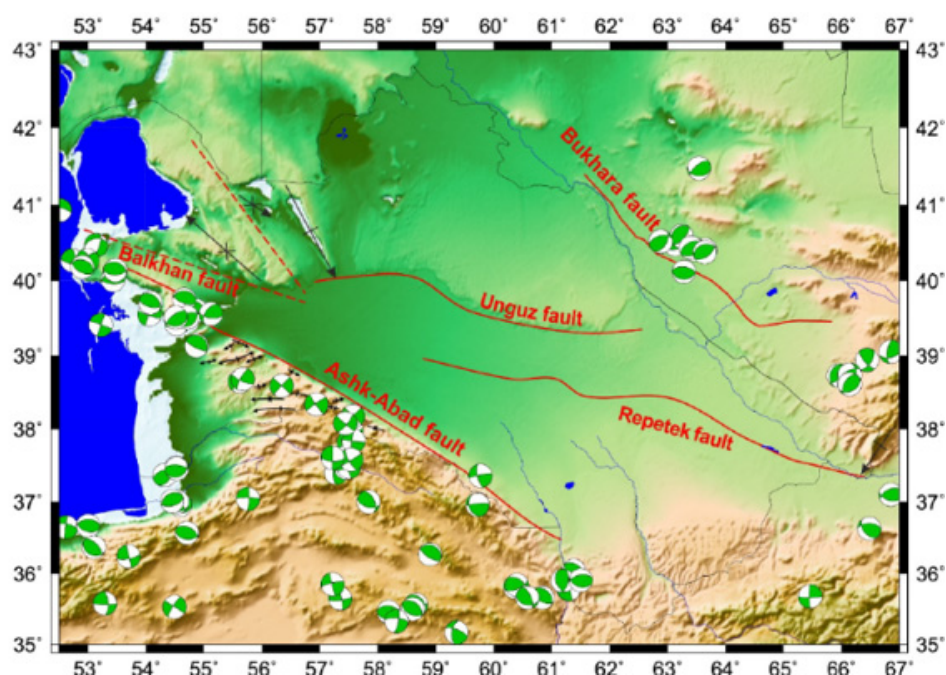
Figure 2-7 Precipitation and Average Temperature in Ashgabat

Figure 2-8 and Figure 2-9 show the epicentre and fault locations of earthquakes with magnitude of 6.0 or greater which have occurred in and around Turkmenistan in the past. Nine of nineteen earthquakes occurred on the Ashgabat fault and the most recent 7.3 magnitude earthquake occurred in 2000.



Source: UNDP Turkmenistan

Figure 2-8 Major Earthquake Occurrence Points around Turkmenistan, M6.0 or higher



Source: Geology and geomorphology of Turkmenistan: A review, Mohammad R. Ghassemi, Eduardo Garzanti

Figure 2-9 Major Locations of Active Faults around Turkmenistan

Table 2-1 Major Earthquakes around Turkmenistan (M6.0 or higher)

No.	Year	Magnitude	Location	Country/ Area
1	818	7.5	Balkh	Afghanistan
2	1175	7.1	Kerkin	Turkmenistan
3	1208	6.2	Amu Darya	Turkmenistan
4	1890	6.5	Astrabad	Iran
5	1893	6.6	Quchan	Iran
6	1895	8.2	Krasnovodsk	Turkmenistan
7	1902	6.2	Termez	Uzbekistan
8	1904	6.3	Mashhad	Iran
9	1907	6.1	Kyzyl-Ayak	Turkmenistan
10	1911	7.5	Afghanistan	Afghanistan
11	1929	7.2	Gifan	Iran
12	1946	7.0	Kazanjik	Turkmenistan
13	1948	7.3	Ashgabat, Turkmenistan	Turkmenistan
14	1970	6.7	Moravian	Iran
15	1976	7.3	Ghazly	Uzbekistan
16	1986	6.2	Caspian Sea	Caspian Sea
17	1989	6.3	Caspian Sea	Caspian Sea
18	1997	6.6	Bojnurd	Iran
19	2000	7.3	Uly Balkan	Turkmenistan

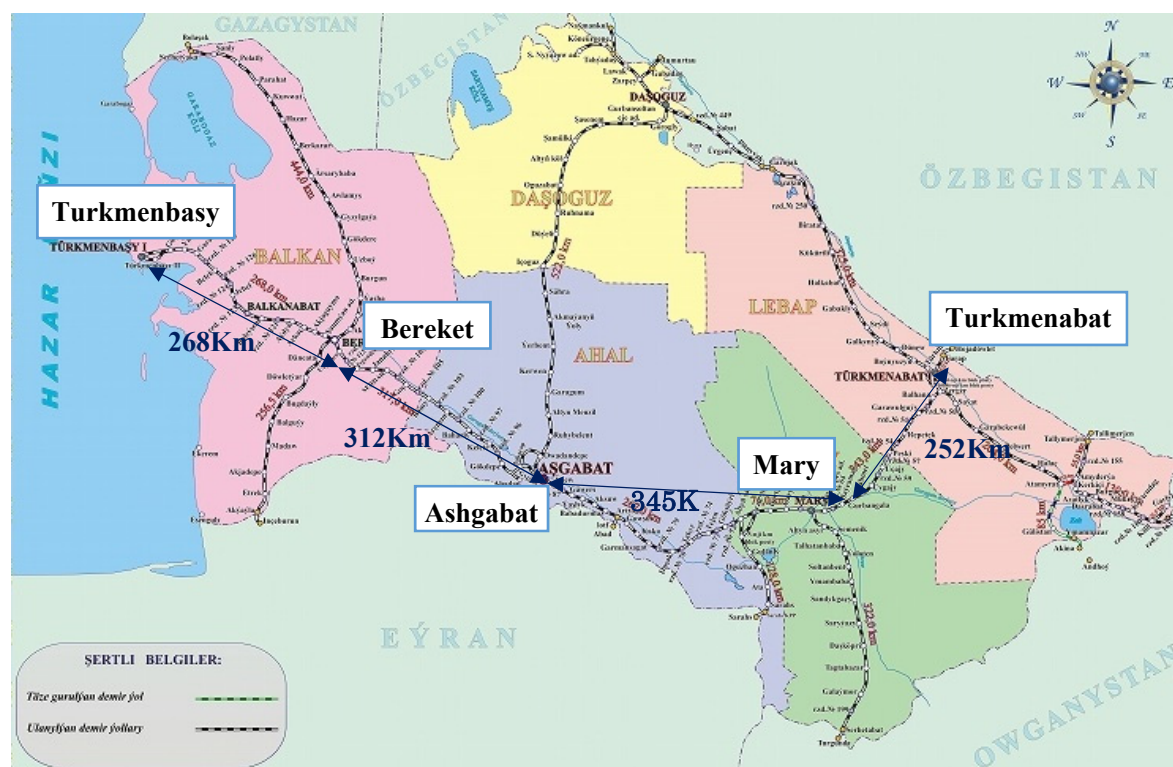
Note : Shaded earthquakes occurred in Ashgabat fault

Source: UNDP Turkmenistan

3. Present Situation of Railway Sector and Study Section

3.1 Route Map

Turkmenistan has a 3,550.9 km long railway network and this study covers 1,176 km of the East-West corridor which extends along Turkmenbasy – Ashgabat – Mary – Turkmenabat.

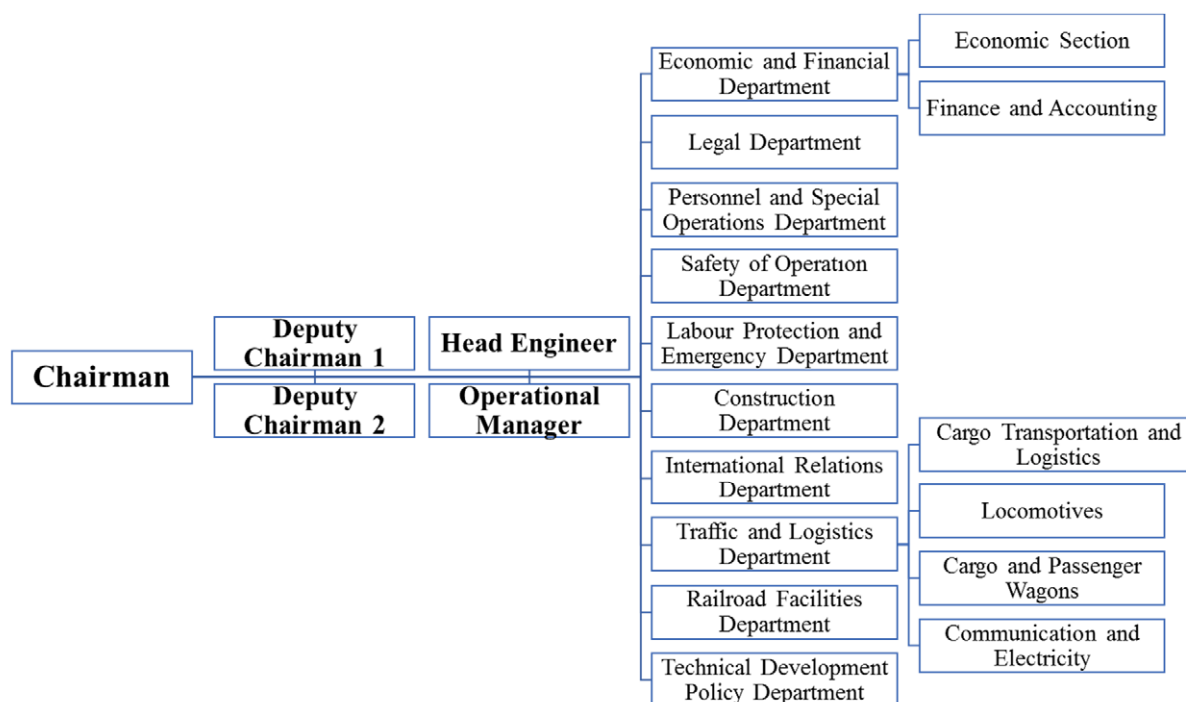


Source: Railway Agency of Turkmenistan

Figure 3-1 Map of the Study Route

3.2 Organization Chart

Based on the information of interview survey, the organization chart of the Railway Agency of Turkmenistan is shown in Figure 3-2.



Source: Study Team

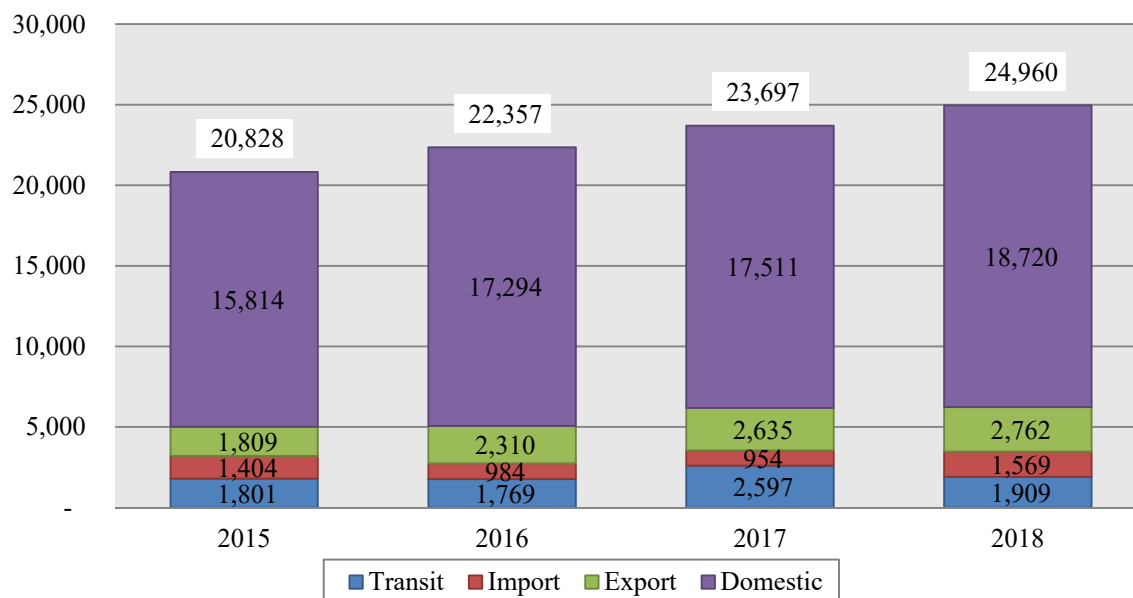
Figure 3-2 Organization Chart of the Railway Agency of Turkmenistan

3.3 Overview of Cargo and Passenger Demand

3.3.1 Cargo Transportation

(1) Past Trend of Domestic, Export, Import and Transit Cargo

By analysing the past data of 2015 to 2018, it is observed that domestic cargo is playing the vital (around 80%) role for railway transportation. Every year the total cargo volume transported by railway for domestic, export, import and transit purpose is increasing gradually as shown in Figure 3-3.

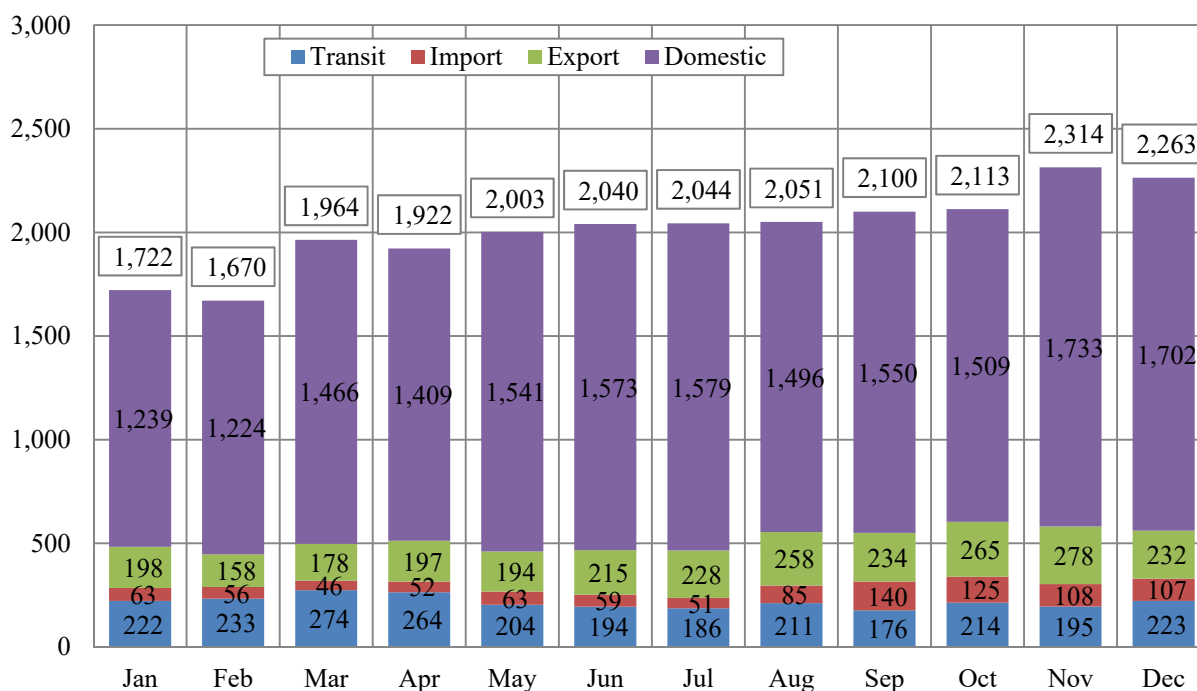


Source: Railway Agency of Turkmenistan

Figure 3-3 Cargo Handling Volume from 2015 to 2018

(2) Monthly Fluctuation

The monthly fluctuation cargo transportation is shown in Figure 3-4. In case of transit, the highest transportation is observed in March, whereas, the non-transit cargo volume was highest in November in 2018

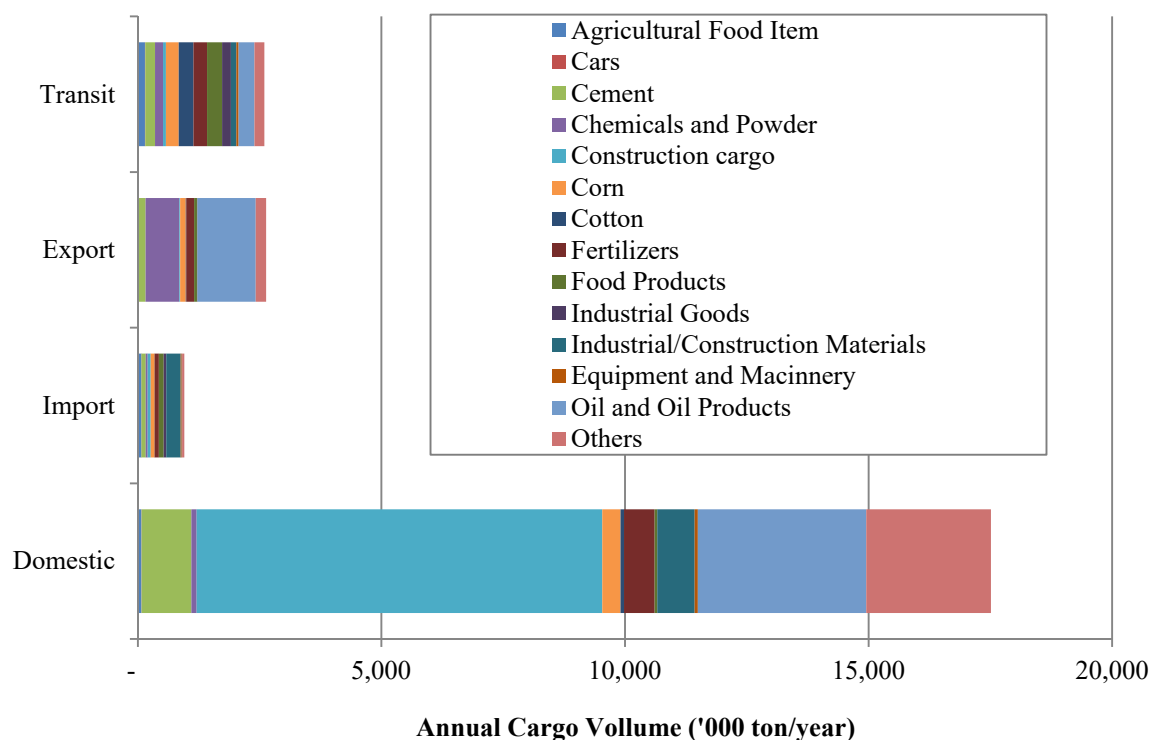


Source: Railway Agency of Turkmenistan

Figure 3-4 Monthly Fluctuation of Cargo Transportation in 2018

(3) Product Type

Cargo handling volume was summarized by origin-destination types (domestic, import, export and transit) and 14 product types based on the detail data received from the RA. Those are: Agricultural Food Item, Cars, Cement, Chemicals and Powder, Construction Cargo, Corn, Cotton, Fertilizers, Food Products, Industrial Goods (finished products), Industrial Construction Materials, Equipment and Machinery, Oil and Oil Products and others.



Source: Railway Agency of Turkmenistan

Figure 3-5 Cargo Handling Volume by Product Type in 2018

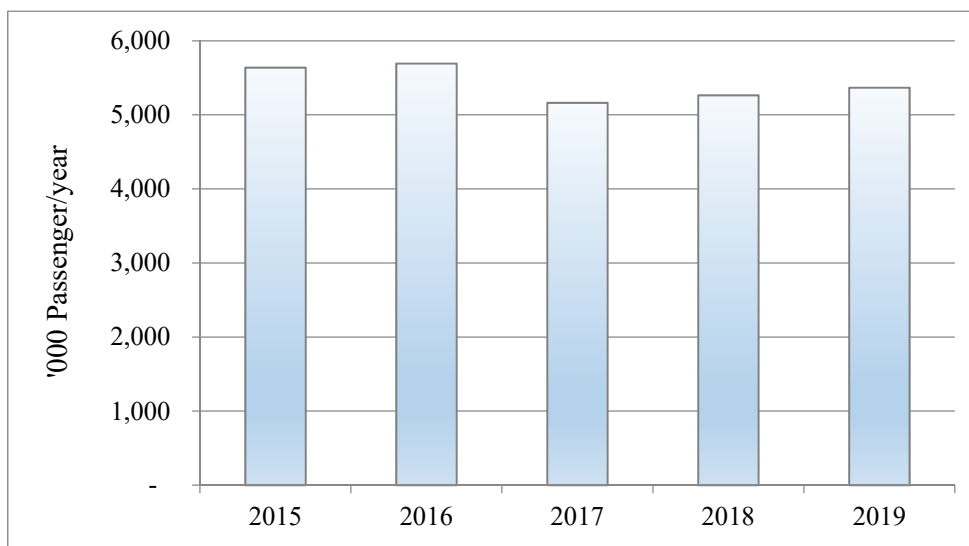
Table 3-1 Cargo Handling Volume by Product Type in 2018 (Unit thousand Ton)

	Domestic	Import	Export	Transit	Sub-Total
Agricultural Food Item	74	72	12	147	305
Cars	2	2	0	5	9
Cement	1,021	90	145	201	1,457
Chemicals and Powder	110	39	694	164	1,006
Construction cargo	8,326	62	18	59	8,465
Corn	374	83	116	264	837
Cotton	74	0	7	303	385
Fertilizers	624	83	163	279	1,149
Food Products	57	102	57	309	524
Industrial Goods	2	53	8	181	243
Industrial/Construction Materials	765	294	3	112	1,175
Equipment and Macinnery	65	22	1	44	132
Oil and Oil Products	3,457	8	1,194	326	4,985
Others	2,560	45	216	204	3,025
Total	17,511	954	2,635	2,597	23,697

Source: Railway Agency of Turkmenistan

3.3.2 Passenger Transportation

Past data (2015-2019) of passenger volume data of the whole country is shown in Figure 3-6 and it is observed that in 2017 suddenly the volume suddenly decreased, however, after that the number of passengers is increaseding gradually.

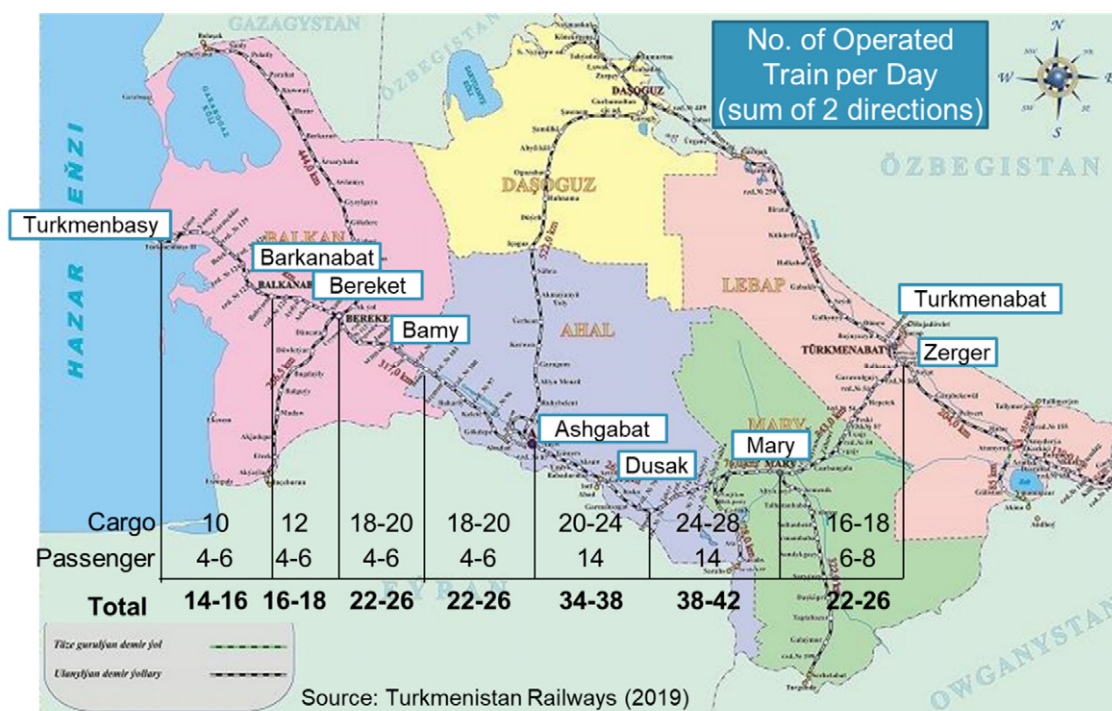


Source: Railway Agency of Turkmenistan

Figure 3-6 Number of Passenger Transported by Railway (2015 - 2019)

3.4 Operation Status

The present number of operating trains in the target section is shown in Figure 3-7. The busiest section is observed from Dusak to Mary, followed by Ashgabat - Dusak. In each section, the number of operating freight trains is greater than the number of operating passenger trains. Most passenger trains are operating at night and freight trains are often operating during the day.



Source: Study Team

Figure 3-7 Daily No. of Train by Section in 2019

At present, cargo trains do not operate according to a timetable, but instead focus on profitability, waiting for the products at the station and operate only when the train reaches to its maximum formation. When the locomotive is absent, it asks for the locomotive when the formation is ready. The maximum towing capacity of a locomotive is 4,200 tons, which is a practical consideration during formation. In the case of formation with empty cargos, it depends on the length of the switching track at intermediate stations. For this reason, additional tracks for preparation and storage of the train is needed until formation is completed.

Signal control is performed by Centralized Traffic Control (CTC) located at the central control centre. The whole corridor is divided into seven sections and each section has a separated room in the centre. Communication with other rooms is made by phone while communication with the train drivers is made by wireless device. However, a major station such as Turkmenbasy controls the signalling system locally communicating with the central control centre. The staff compare the large monitor with a printed train operation diagram and write down actual operation into the diagram. In addition to the train operation

diagram, the sheet also has a column to write down the information for the departure and arrival of the trains.

Locomotives for cargo trains have two drivers' compartments and those can be two types: one with two drivers' room on both ends and the other with the drivers' room on one end. On the other hand, locomotives for passenger trains only have one drivers' compartment with two drivers' room on both ends. According to the RA, it can also be operated from the drivers' compartment fitting in the middle of the freight train.

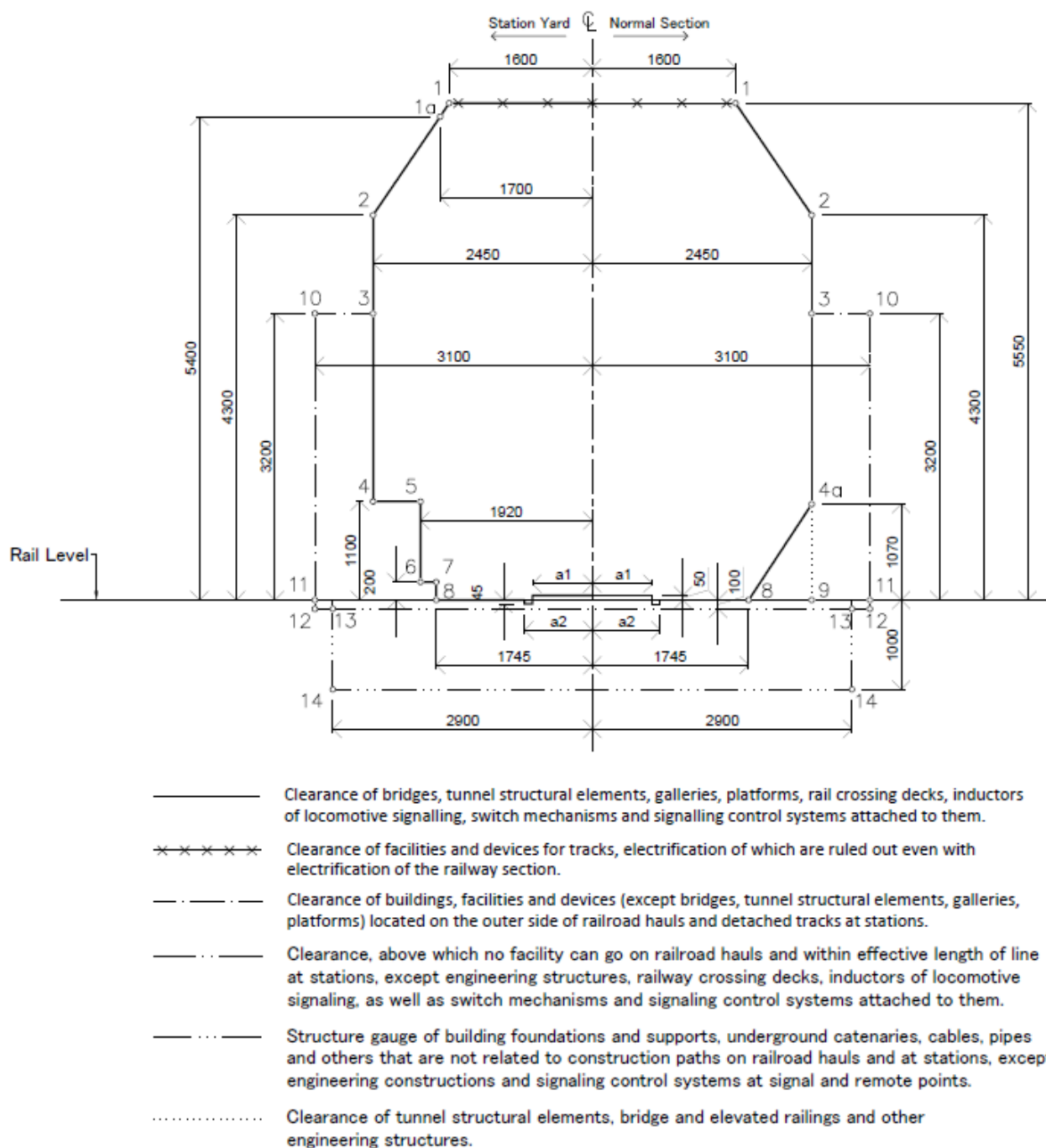
Cargo wagons are connected by only one air hose and it can be an issue for the air transmission time (time needed for braking by pressure reduction by the locomotive to reach the last train) when the train is long and the emergency braking distance is minimum 800m. Therefore, there is a bottleneck for achieving high speed.

3.5 Civil Structures

In Turkmenistan, GOST (GOsudarstvennyy STandard, осударственный стандарт) design standard used in CIS countries and Russia is adopted for the design of railway civil structures.

3.5.1 Construction Gauge

In Turkmenistan, a railway network of 3,550.9 km has been developed so far, all of which are non-electric. Figure 3-8 shows the construction gauge for the non-electrified section.



Source: Turkmenistan Railway Agency (Extract only the non-electrification related parts)

Figure 3-8 Construction Gauge for Non-Electrified Section

3.5.2 Roadbed and Track

(1) Specifications for Current Track Structure and Track Alignment

In Turkmenistan, a ballasted track with a gauge of 1,520 mm is adopted. The standard track cross section is shown in Figure 3-9.

Table 3-2 Specifications for Current Track Structure and Track Alignment (Turkmenabat - Turkmenbasy)

Item		Specification	Remarks
Gauge		1,520 mm	Russian Standard
Maximum Axle Load		25 tons	Design value
Track	Rail Standard	65 kg/m	GOST Standard
	Design Ballast Thickness	350 mm	Directly under sleeper
	Rail Joint	Welding/Joint Plate	Continuous welded rail (CWR) up to 700 m
Design Maximum Speed		120 km/h (Passenger Train)	Actual maximum operating speed is approximately 70 - 80 km/h
Minimum Curve Radius		R=504 m	
Gradient		15‰ or less	
Turnout		9#, 11#	

Source: Study Team

(2) Current Conditions of Track and Roadbed

As mentioned above, it is necessary to study in detail regarding the lateral force of the ballast shoulder width. In the case that all items excluding the ballast shoulder width are maintained according to the standard, there will be no problems for the passenger train to operate at its maximum design speed of 120 km/h. However, in actuality, the design speed cannot be reached due to the insufficiency of the track maintenance. The cCurrent conditions of the track and roadbed confirmed on site are explained below.

1) Roadbed

It is considered that the roadbed is well tamped since the roadbed itself has been in existence for more than 130 years since the opening of Turkmenistan Railway in 1885, and also currently it is mainly run under Chinese locomotive (DF8B) with an axle load of 23 tons. Furthermore, since the same design load is adopted even after railway modernization, it is considered that there is no need for roadbed improvement. However, locations where mud-pumping induced by poor drainage were confirmed on site as shown in Figure 3-10 .



Source: Study Team

Figure 3-10 Roadbed Mud-pumping

2) Ballast

As shown in Figure 3-11 locations in where the soil under ballast is visible or the top of the sleeper end is not filled with the ballast were confirmed at various points here and there on site. At the locations where the top of the sleeper end is not filled with the ballast, the exposure of 3 layers of Prestressed Concrete (PC) cables out of 6-layer arrangement were observed. At the locations where there is a lack of ballast and the track panel is supported by small particle size soil, it is highly possible that ground settlement would occur due to repeated load of trains. Besides, at the locations that are lacking of ballast at the top of the sleeper end, the track cannot resist the lateral force of the train which would easily end up with track irregularity; therefore, high speed trains cannot be operated at the said locations. In Turkmenistan, it is highly possible that the lack of ballast has caused the track irregularity and low speed operation of the trains. Consequently, it is necessary to have proper maintenance for ballast. Note that there are 6 ballast quarries in Turkmenistan as shown in Figure 3-12 .



Source: Study Team

Figure 3-11 Lack of Ballast



Source: Study Team

Figure 3-12 Ballast Quarry Location Map

3) Sleeper

Basically, PC sleepers are used for the mainline, and wood sleepers are used at the turnout sections. According to the basic measurement on site, about 37 sleepers or more are placed every 25 m, the interval of the sleeper seems to be no problem considering the passing tonnage and the maximum design speed. However, some damaged sleepers are confirmed on site as shown in Figure 3-13 and expeditious replacement of the sleepers is required during daily maintenance. At present, there is only 1 sleeper factory in Baharly with a production capacity of 500,000 pieces per year.



Source: Feasibility study on transport system in Turkmenistan (2015)

Figure 3-13 Damaged Sleeper

4) Rail

The current rail is a 65 kg Rail of GOST standard, which has a length of 700 m and is welded to a standard length rail of 25 m (or 12.5 m). At the expansion joint section, rails with a length of 12.46 m, 12.44 m and 12.40 m are inserted as shown in Figure 3-14 .Since there is no increase in axle load even after railway modernization, it is considered that there is no problem with the current specification of 65 kg Rail. However, since damaged rail ends (Figure 3-15) and track irregularity have occurred in actuality, replacement and improvement of the rail is required.



Source: Study Team

Figure 3-14 Continuous Welded Rail in Turkmenistan



Source: Study Team

Figure 3-15 Damaged Rail-end

5) Track Maintenance

In Turkmenistan, there are 2 types of standards regarding track maintenance, Rail Maintenance Standard and Daily Maintenance Standard for Bridge & Tunnel, and 4,952 workers are engaged in maintenance work on the 3,550.9 km railway network. Except for large-scale renovation, maintenance work is basically conducted by human power since only 3 Multiple Tie Tampers¹ (MTTs) are in possession by the country due to the high cost of a special operator for MTT.

6) Turnout

Turnout of 9# and 11# were adopted in the main line. As shown in Table 3-3 ,a total of 327 turnouts

¹ Machines that conduct tapping (ballast tamping), leveling (rail level adjustment) and lining (vertical and horizontal alignment correction) all at once.

were installed between Turkmenabat - Ashgabat - Turkmenbasy.

Table 3-3 Number of Turnout Location between Major Stations

Section	Number of Turnout Location
Turkmenabat - Mary	90
Mary - Ashgabat	98
Ashgabat - Turkmenbasy	139
Total	327

Source: Turkmenistan Railway Agency

(3) Current Track Alignment

1) Curve Radius

The curve radiuses of the alignment between Turkmenabat - Ashgabat - Turkmenbasy are summarized in Table 3-4 . The number of curves in the section is 292, and the minimum curve radius is R=500 m. The number of curves with a radius of 1,000 m or less is 16 out of a total length of 1,176km which is a relatively small number.

Table 3-4 Curve Radius of the Alignment between Turkmenabat - Turkmenbasy

Curve Radius	Number of Location
504 m $\leq$ R $\leq$ 850 m	10
850 m $<$ R $\leq$ 1,000 m	6
1,000 m $<$ R $\leq$ 2,000 m	132
2,000 m $<$ R $\leq$ 3,000 m	104
3,000 m $<$ R $\leq$ 4,000 m	20
4,000 m $<$ R $\leq$ 6,000 m	20
Total	292

Source: Turkmenistan Railway Agency

2) Gradient

Table 3-5 shows the gradient of the alignment between Turkmenbat - Ashgabat - Turkmenbasy. The adopted gradient is 15‰ or less.

Table 3-5 Gradient between Turkmenbat - Ashgabat - Turkmenbasy

No.	Section	Length [km]	Breakdown					
			Horizontal Section [km]	Inclined Section [km]	Gradient			
					4 % or less	4,1 - 8 %	8,1 - 15 %	Over 15 %
1	Turkmenabat - Mary	252	68.2	175	117.5	55.2	2.3	0
2	Mary - Ashgabat	344	68.6	275.1	204	68.6	2.5	0
3	Ashgabat - Turkmenbasy	580	120.4	439.6	304.5	121.5	13.6	0
	Total	1176	257.2	889.7	626	245.3	18.4	0

Source: Turkmenistan Railway Agency

3.5.3 Bridge and Drainage Culvert

(1) Railway Bridge

Some bridges between Turkmenabat - Ashgabat - Turkmenbasy were built in 2008 and some are under renovation, but most bridges were built between 1885 and 1920 which are nearly 100 years old. The main superstructure types of the existing bridges in the target section are as below.

- Steel Through Truss Girder
- Steel Through Plate Girder
- Reinforced Concrete Girder
- Pre-stressed Concrete Girder



Steel Through Truss Girder



Steel Through Plate Girder



Reinforced Concrete Girder



Pre-stressed Concrete Girder

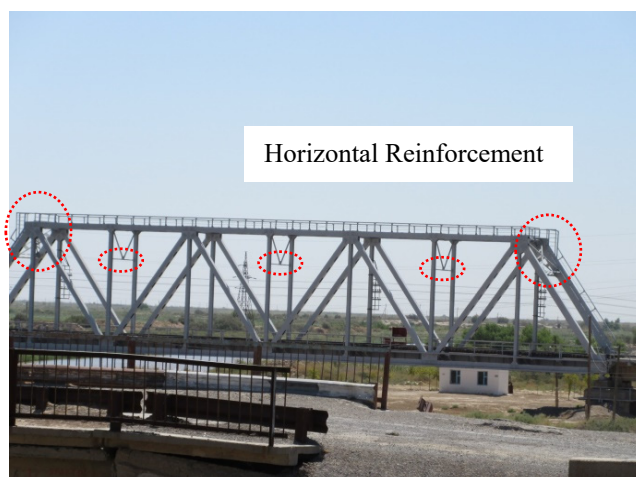
Source: Study Team

Figure 3-16 Superstructure Type

1) Horizontal Reinforcement Bar for the Steel through Truss Girder

As shown in Figure 3-17 a horizontal reinforcement bar is installed at the entrance and middle part of the steel through truss girder bridge. In the case of railway electrification, higher construction gauge compared to non-electrification is required, therefore, it is extremely important to identify the clearance

between the rail level and the bottom of the horizontal reinforcement bar. Clearance investigation of the through truss girder bridge within the target section has not been conducted under this survey, therefore, in the future supplementary survey or detailed design stage, it is necessary to conduct clearance investigation for all corresponding locations. As a reference, clearance investigation was conducted at Amu Darya River between Turkmenabat and Farab which is outside of current target section. Clearance of 6.784 m between the rail level and the bottom of horizontal reinforcement bar was confirmed as shown in Figure 3-18 .



Source: Study Team

Figure 3-17 Horizontal Reinforcement Bar for the Steel through Truss Girder



Source: Study Team

Figure 3-18 Clearance of Steel through Truss Bridge over the Amu Darya River (Reference)

2) Drainage Culvert

The main structure types of the drainage culverts between Turkmenabat - Ashgabat - Turkmenbasy are as below.

- Box Culvert
- Pipe Culvert



Box Culvert

Source: Study Team

Figure 3-19 Drainage Culvert

3.5.4 Overbridge

(1) Overpass

Between Turkmenabat - Ashgabat - Turkmenbasy, especially in urban areas, overpasses are constructed to avoid an at-grade intersection of road and railway. As mentioned previously, since a higher construction gauge is required for railway electrification, it is extremely important to identify the clearance between the rail level and the bottom of the overpass. Ashgabat Station were conducted under this survey, therefore, in the future supplementary survey or detailed design stage, it is necessary to conduct clearance investigation of all overpasses within the target section. As shown in Figure 3-20 , the smallest clearance of 7.461 m was confirmed.



Source: Study Team (Map is used from Open Street Map)



Source: Study Team

Figure 3-20 Clearance under the Overpass near Ashgabat Station

(2) Pedestrian Bridge

There are 7 pedestrian bridges between Turkmenabat - Ashgabat - Turkmenbasy. According to the basic measurement at Ashgabat Station, clearance between the rail level and the bottom of the pedestrian bridge is 7.296 m. In the future supplementary survey or detailed design stage, it is necessary to conduct clearance investigation of all pedestrian bridges within the target section and to review whether the renovation is required due to electrification.



Source: Study Team

Figure 3-21 Clearance under the Pedestrian Bridge at Ashgabat Station

3.5.5 Level Crossing

There are 99 level crossings between Turkmenabat - Ashgabat - Turkmenbasy, of which 32 have a protection device installed. As shown in Figure 3-22, 2 types of protection devices, automatic gate type and roadway flip-up type, were confirmed on site.



Automatic Gate Type



Roadway Flip-up Type

Source: Study Team

Figure 3-22 Level Crossing

3.6 Cargo Station and Passenger Station

3.6.1 Cargo Station

Cargo stations include dedicated cargo stations and stations operate both passenger and cargo trains. Among the study sections, a field survey was conducted at Gypjak which is one of the main cargo stations, Turkmenbasy 1 and Turkmenbasy 2. The observation points of the field survey are described below.

(1) Gypjak

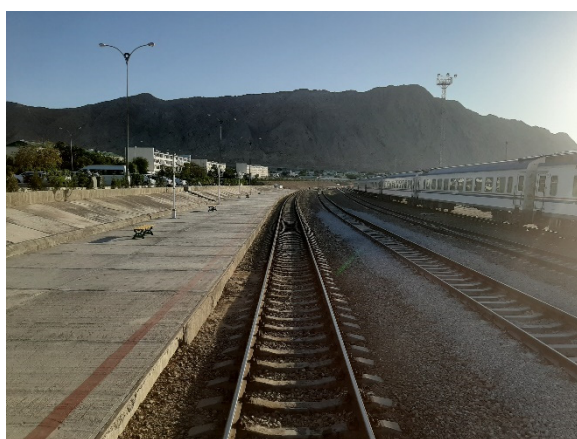
- There are two tracks of container platform and also bulk area. RA also transports heavy equipment manufactured by Komatsu.
- RA is transporting glass, which is manufactured using the sand from the Karakum Desert. Other steel products are also transported.
- RA also transports electricity poles (rectangular cross section) from Lebap Province.
- Cranes are usually used for loading and unloading at the container platform, but forklifts are also used sometimes. Crane loading applies a four-corner suspension method, and it takes goods in and out directly from a container without moving the container itself.
- In the case of moving containers to foreign countries such as Kazakhstan, customs officers check the cargo at the station and at the attendance of the sender.
- In the case of transportation of transit containers for the neighbouring countries such as Kazakhstan, those containers are visually confirmed by the customs officials at the station and seal those on the spot.
- At present, unloading the containers and cargo requires time. In order to increase the transportation capacity, it is necessary to shorten the cargo handling time and increase the rotation speed of the cargo handling line or to add a new platform.

(2) Turkmenbasy 1 and Turkmenbasy 2

- Turkmenbasy 1 Station is directly connected to Turkmenbasy Port and transports cargo wagons to and from Azerbaijan and transshipment of cargos from ship to trains. On the other hand, Turkmenbasy 2 mainly deals with the transportation of petrol, diesel, and aviation fuel, as it is adjacent to the petrochemical plants.
- Each station has signal offices where two groups of dispatchers, who operate signals separately for train arrival and departure and station operation. The person in charge of arrival and departure exchanges information with the central command, performs signal operations for train arrival and departure and train composition on the departure line, considering the line change prepare the arrival line empty. The person in charge of station yard, instructs field staff through the wireless device. Turkmenbasy 1 Station is relatively new and operations are held on one floor, however, Turkmenbasy 2 Station is older and operations are controlled from two rooms.
- There is an inspection and repair workshop at Turkmenbasy 2 Station, where light maintenance work of the locomotives is performed. There are three lines for train departures and cargos from the workshop is waiting. The returned empty cargos are washed and put into the workshop.
- It has three DL switchers, including one for backup, for track management inside the station and three

main line machines are used for transportation to and from Balkanabat. When there is a shortage of locomotives, locomotives are sometimes forwarded from here.

- At Turkmenbasy 1 Station, it seems that there is enough space on the track to place (reload) the cargos. It is said that Turkmenbashi 2 Station will be filled with the current peak (capacity 800 to 900 cars), It is necessary to increase capacity, shorten the loading time in the factory or reinforce loading equipment, and improve the capacity of freight car washing.
- Turkmenbasy 1 Station seems to have extra space on the unloading track for cargo trains. On the other hand, Turkmenbasy 2 Station is currently fully occupied with 800 - 900 cargos. Hence, in order to drastically increase the number of trains in the future, the capacity improvement for departure/arrival track, shortening of loading/unloading time in the workshop, improvement of cargo train washing facilities is likely to be required.



Turkmenbasy1 Station



Turkmenbasy2 Station

Source: Study Team

Figure 3-23 Turkmenbasy Cargo Station

3.6.2 Passenger Station

The existing passenger station has been rebuilt in the last few years and is in relatively good condition (Figure 3-24). At the station, there is no ticket gate to enter the platform and ticket examination is performed on the platform. Regarding the platform, some stations such as Ashgabat Station, Bereket Station and Balkanabat Station, an elevated platform was adopted to avoid using a step from the platform to the vehicle entrance. On the other hand, stations such as Turkmenbasy Station with a low platform has a step between the platform and the vehicle entrance (Figure 3-25).



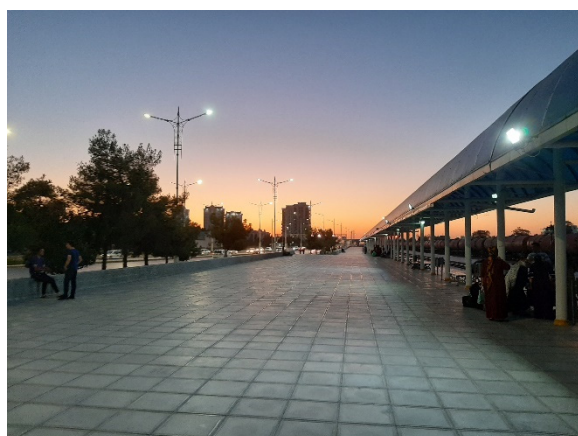
Turkmenbasy Station



Turkmenabat Station

Source: Study Team

Figure 3-24 Passenger Station



Ashgabat Station



Turkmenbasy Station

Source: Study Team

Figure 3-25 Passenger Station Platform

3.7 Signal and Telecommunication

The outline of the interview with the Turkmenistan Railway Agency is described below.

- Generally, signal and telecommunication systems need to be improved because they were introduced in the 1970s.
- Ashgabat Station and Bereket Station have new equipment for both signal and telecommunication systems.
- The telecommunication system at Turkmenbasy Station is new equipment.
- Laying optical fibre cables for more than 700 km, the current usage rate is about half. It is necessary to lay an optical fibre cable from Ashgabat to Turkmenabat.

- Telecommunication lines are operated in cooperation with the Ministry of Communications.
- The dispatcher is operating from the operation centre by the operation management system.
- 30 dispatchers and 4 leaders are enrolled and operated by 7 people in 12 hours shifts.
- For Turkmenbasy Station, the signal and telecommunication systems are managed at the station.
- There is no plan to improve signal and telecommunication equipment.
- Expect a new system to be introduced at the time of electrification. Even if there are no electrification plans, improvement of the system is needed. Replacement parts for signal and telecommunication systems are a problem, and we have trouble finding replacement parts in case of failure.
- A new signal and telecommunication system (made by Bombardier) was introduced for the lines from Bereket to Kazakhstan and between Bereket and Iran.

3.7.1 Signal

According to the interview survey, the track circuit is approximately 1.5 km and a traffic light is installed. Although several types of Russian train detection devices have been introduced, information on the number of various types of equipment was not available. The signals are installed on poles and on the premises of station which is 2 or 3 aspects. It is necessary to confirm the criteria for the installation for signals and the use of the signs in future surveys. In this survey, the interlocking device was excluded from the actual machine survey. There are stations of various sizes in the target line area, from large stations to interchange points. At some stations, tracks are connected to nearby factories and plants.

The investigation at Turkmenbasy Station was only in the operation room, and the display on the operation screen was confirmed. Turkmenbasy Station has relatively new facilities. The route control of the detention line is performed at the station.

As for the operation management system, Ashgabat is operated as a control centre. The system was introduced in the 1980s, and there are requests from Turkmenistan to update the system. It is necessary to collect detailed information on the sections controlled by the control centre and the operation of trains that cross two sections in a future study.

In the future, it is necessary to perform a detailed check of the operation of the system if the system configuration, operation sharing, and control range of the entire Turkmenistan. In addition, the number of trains that will be operated at the same time will greatly increase due to future speed improvements and more efficient operation plans, so it is necessary to check the upper limit in the specifications of the existing operation control system. Some major specifications are the number of simultaneous trains, number of stations, traffic rescheduling function, timetable creation and correction function, availability of track layout change (double track and change of track layout inside yard premises).

3.7.2 Telecommunication

As for telecommunication facilities, information on cable lengths throughout Turkmenistan was obtained, but no information was provided on the network configuration of the surveyed section. Optical fibre has been introduced in some facilities. Monitoring by network cameras is also performed inside the station. The types and details of the communication specifications used for calls between stations and control centres and trains were unknown. Although there is still room for use of existing optical fibre cables, there is a demand for networking by further laying of new optical fibre cables.

3.8 Rolling Stock, Depot and Workshop

3.8.1 Rolling Stock

Table 3-6 shows the number of rolling stocks present under the jurisdiction of the Railway Agency of Turkmenistan.

Table 3-6 Number of Locomotives under the RA

Type	Usage	Model	Country of Origin	Number
Diesel locomotive Track gauge 1,520mm	Freight	2TE10Y	Ukraine	6
		DF4B(CKD9C)	PRC	38
		DF8B(CKD9C)	PRC	46
		TE33A	Kazakhstan	1
		(Total)		(91)
	Passenger	DF8B(CKD9C)	PRC	25
		(Total)		(25)
	Switcher	CKD6E	PRC	56
		CME-3	Czechoslovakia	12
		TEM-2	Russia	1
		TEM-18	Russia	11
		TGM-4a	Russia	1
		TGM-4b	Russia	1
		TGM40-01	Russia	1
		(Total)		(83)
	Sum of locomotive			199
Cargo			Russia • Ukraine	11,065

Source: Railway Agency of Turkmenistan (As of 2019.12.23)

* The diesel locomotive for freight trains is a two-car linked type, with 12 wheels.

* There is only one diesel locomotive for passenger trains, and the number of wheels are 6

* Newly introduced locomotive made in China has a diesel generators driven by a DC motor

※Newly introduced locomotive made in China has a diesel generators driven by a DC motor



Locomotive Model TE33A from Kyrgyzstan (Cargo)



Locomotive Model CKD9C from China (Cargo)



Locomotive Model CKD6A from China (Passenger Train)

Source: Study Team

Figure 3-26 Most Common Locomotives using in Turkmenistan

3.8.2 Inspection Type and its frequency

Table 3-7 shows the type of inspection and its frequency carried out by the RA.

Table 3-7 Inspection Type and its Frequency

Type	Inspection Type	Frequency	Duration
Diesel locomotive	Locomotives technical maintenance inspection No.1 is the daily visual inspection		
	Locomotives technical maintenance inspection No.2 (regular)	Every 200km - 600km	3 hours
	Locomotives technical maintenance inspection No.3 (periodic)	Every 20,000km	18 hours
	Locomotives technical repair work No.1	Every 60,000km	36 hours
	No. 2 existed before, now this inspection is not carried out		
	Locomotives technical repair work No.3	Every 300,000km	14 working days

Type	Inspection Type	Frequency	Duration
	Major repair work (overhauling)	Every 900,000km -960,000km	Performed outside Turkmenistan, send to abroad (to the manufacture), so duration is unknown
Cargo Wagon	When they stop at a station, the train will be inspected at station		
	Up to 12 months (for more than 20 years old) or 24 (for new ones) or 36 months (for brand new) the wagons can be used or 210,000km, whichever is reached faster.		8~9 hours (1 working day)

Source: Railway Agency of Turkmenistan

Note: The information in the table is applied only to locomotives for the main line

3.8.3 Depot and Workshop

Table 3-8 shows list of depots and workshops indicated by the type of rolling stocks handled in each place.

Table 3-8 Rolling Stock Type for each Depot/Workshop

Location	Vehicle Type	
	Cargo Wagon	Diesel locomotive
Turkmenbasy	○	○
Bereket		○
Serdar	○	
Ashgabat	○	○
Dpsak		○
Sarabs		○
Mary	○	○
Amyderiya		○
Turkmenabat	○	○
Dasoguz		○
Total	5	9

Source: Railway Agency of Turkmenistan

※ Bereket, Serdar, Ashgabat, Mary and Turkmenabat are the workshops for diesel locomotives

※ Overhauling the cargo wagons are carried out in Serdar

※ Overhauling of locomotives are outsourced to Russia

4. Formulation of the Basic Plan

4.1 Review of Relevant Plans

The relevant plans which could affect future demand forecasting of the railway sector have been analysed. The national plan named “Socio-economic Development Plan of the President of Turkmenistan for 2019-2025” published by the presidential office has a list of future plans of factories and commercial plants of different sectors and products. To analyse the future demand forecast the location of the factories and possible destinations of these products have been considered. The Railway Agency also formulated their own target plan for cargo transportation for the period of 2019-2025 and this target volume have been used to design future case scenarios.

In the plan for Industry and Communication Sector of Turkmenistan (2019-2025), it is mention that, the Railway Agency is considering the modernisation of the current railway system and infrastructure in order to reduce cargo transportation time (i.e. increasing the average speed of trains). Railway sector development should include the following aspects in order to improve the quality of cargo and passenger transportation:

- Attraction of private investment;
- Application of modern technology;
- Preparation of capable and skillful personnel;
- Modernization of existing railways;
- Introducing digitalized management and sales system;
- Improvement of environmental and ecological quality by the implementation (purchasing) of green eco-railway-vehicles (ecologically clean locomotives, etc.) and electrification of railways;
- Implementation of reinforced-concrete sleepers that meet international standards.

4.2 Future Demand Forecast

4.2.1 Introduction

The railway cargo transportation of Turkmenistan is composed of basically four types: domestic, export, import and transit. In order to carry out the future demand forecast of cargo transportation, origin – destination based (station to station) product type wise past data were expected to be received. However, during the field survey it was understood that origin-destination wise past data are not available for all types of cargo (only transit data was available). Therefore, the future demand forecast of cargo has been carried out by properly using the available data. In the next stage of the study a more detailed demand forecast needs to be carried out by collecting more detailed raw data.

For cargo transportation forecast, in principle the cargo transportation has direct correlation to the country's GDP. The GDPs of neighbouring countries are considered for transit cargo, and the GDP of Turkmenistan are considered for non-transit trips (domestic, export and import). In this study, the future demand is forecasted by using the elasticity method between the cargo and GDP, for cargo and passenger number and population, and for passengers. For the unavailable origin-destination data (domestic, import and export), the current station-and product- wise cargo transportation OD was estimated by using the Fratar method with product-wise cargo handling volume at each station and reciprocal numbers of the distance between each station. With this current station- and product- wise cargo transportation OD, the future volume is estimated using the elasticity method.

4.2.2 Assumptions for Future Demand Analysis

(1) Socioeconomic Framework

As the International Monetary Fund (IMF) data is already approved by the Turkmenistan Government before publication, in principle the IMF data has been used for socioeconomic analysis.

1) GDP of Turkmenistan and neighbouring countries of Turkmenistan

The GDP of Turkmenistan and neighbouring countries has been analysed for the future projection of cargo demand. As described before, domestic import and export cargo demand have direct correlation with the country's GDP. For the transit demand forecast, the future GDP growth of the neighbouring countries are also taken into consideration. In addition to the countries under the Central Asia Regional Economic Cooperation Program (CAREC), China and Turkey also have important trade relations with Turkmenistan. Therefore, for transit forecasting the elasticity is calculated with the total GDP variations of all these countries.

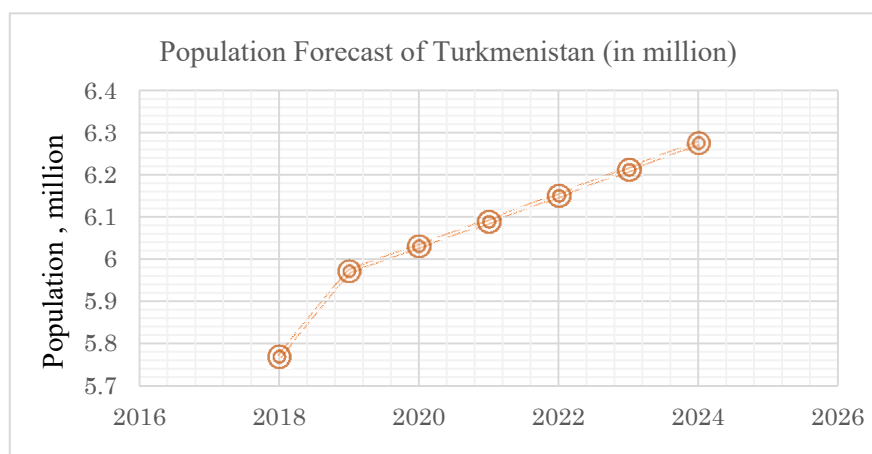
Table 4-1 Future Total GDP of Turkmenistan and Neighbouring Countries (2010 constant), billion USD

Country	2017	2018	2019	2020	2021	2022	2023	2024
Afghanistan	20.7	21.0	21.6	22.3	23.2	24.3	25.5	26.9
Azerbaijan	56.6	57.4	59.3	61.1	62.4	63.4	64.4	65.5
China	10,131.9	10,800.6	11,481.0	12,181.3	12,912.2	13,648.2	14,412.5	15,205.2
Georgia	15.9	16.7	17.4	18.3	19.3	20.3	21.3	22.4
Kazakhstan	196.0	204.1	210.6	217.3	224.5	231.9	242.6	253.5
Kyrgyz Republic	6.6	6.9	7.1	7.4	7.6	8.0	8.3	8.6
Pakistan	240.9	253.9	261.3	268.6	276.1	283.6	291.0	298.2
Tajikistan	9.1	9.8	10.3	10.7	11.2	11.7	12.2	12.7
Uzbekistan	63.5	66.8	70.1	74.0	78.4	83.1	88.1	93.4
Iran	560.9	581.9	547.0	548.1	553.1	558.6	564.2	570.4
Turkey	1,206.0	1,237.0	1,206.1	1,236.2	1,273.3	1,311.5	1,357.4	1,404.9
Turkmenistan	42.1	44.7	47.6	50.4	53.2	56.2	59.4	62.8

Source: 2017-2018 World Bank (<https://data.worldbank.org/>); 2019-2024 Growth Rate of IMF

2) Population of Turkmenistan

Future population forecast of IMF has been used in order to forecast future population growth as shown in Figure 4-1 and annual average growth rate between 2018 and 2024 is calculated as 1.41%.



Source: IMF

Figure 4-1 Future Population Forecast of Turkmenistan

(2) Planning Horizon

The planning horizon of the study is set as 2025 (short term), 2040 (mid-term) and 2055 (long term). During the detailed study, the future forecast needs to be reviewed based on more recent data (both passenger and cargo) and economic trend.

(3) Future Growth Rate Calculation

1) Consideration of the Scenarios

In order to calculate the future growth rate 3 scenarios are considered based on the collected data and analysed documents.

(a) Scenario 1

Future target of railway cargo volume transportation has been set by RA for the period of 2020~2025 and the AAGR is calculated as 1.64% and future growth rate is considered to be same till 2055, under scenario 1.

(b) Scenario 2

From RA, previous cargo transportation data between 2015~2018 has been received and the AAGR is calculated as 3.22%. Under this scenario, future growth rate is considered to be constant up to 2055.

(c) Scenario 3

This scenario is estimated by multiplying the GDP growth rate projection of IMF by elasticity value of cargo volume and GDP.

For non-transit cargo (domestic, import, export) forecast, the elasticity value is calculated as below:

$$\text{Elasticity Value 1 (e1)} = \frac{\text{Change Rate of Non – Transit Cargo (\%)}}{\text{Change Rate of GDP of Turkmenistan (\%)}}$$

For transit cargo forecast, the elasticity value is calculated as below:

$$\text{Elasticity Value 2 (e2)} = \frac{\text{Change Rate of Transit Cargo (\%)}}{\text{Change Rate of GDP of Turkmenistan and Neighbouring Countries (\%)}}$$

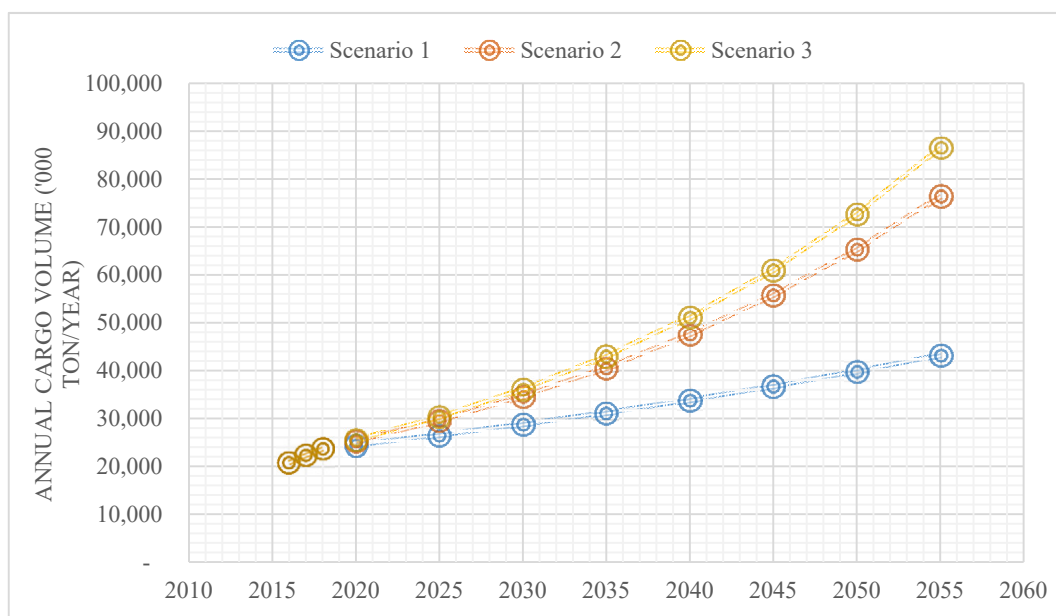
Table 4-2 Growth Rate Calculation using Elasticity Value

	GDP Growth (AAGR)			Elasticity Value	Adjusted Growth Rate		
	2019-20	2021-25	2026-55		2019-20	2021-25	2026-55
Transit	5.11%	5.21%	5.13%	0.72	3.66%	3.73%	3.67%
Export	6.15%	5.64%	5.70%	0.62	3.82%	3.50%	3.54%
Import	6.15%	5.64%	5.70%	0.62	3.82%	3.50%	3.54%
Domestic	6.15%	5.64%	5.70%	0.62	3.82%	3.50%	3.54%

Source: Study Team

3) Selection of Scenario

Future cargo volume has been forecasted using 3 different scenarios, which is shown in Figure 4-2.



Source: Study Team

Figure 4-2 Forecast of Future Cargo Volume Using Different Scenarios

Out of 3 scenarios, scenario 3 is considered more applicable, as it considers both the GDP change of Turkmenistan and its neighbouring countries as well as past trends of cargo transportation. Even though scenario 3 has the highest growth rate, it is safer for the railway system design to take higher values.

(4) Future Demand from Industrial Development

Future industrial plan, “Socio-economic Development Plan of the President of Turkmenistan for 2019-2025”, prepared by the Turkmenistan Government which is described in section 4.1 has been considered in the future forecast of cargo volume. In addition, the factories constructed by Japanese companies are also analysed (as shown in Table 4-3) and the future possible cargo demand is adjusted considering the product type.

Table 4-3 List of the Factories Constructed by the Japanese Companies

Name of the Plant	Counterpart	Location	Capacity
Gas-fired power plant facilities	National Electricity Corporation Turkmen Energo	Lebap Region	400MW
Chemical Fertilizer Plant	National Chemical Corporation Turkmenistan	Balkan Region	Amonia 2,000 Ton/day Urea 3,500 Ton/day
Ethylene Complex Plant	National Gas Corporation Turkmen Gas	Balkan Region	Ethylene (400,000 ton/ year) High density polyethylene (400,000 ton/ year) Polypropylene (80,000 ton/ year)
Gas to Gasoline Plant	National Gas Corporation Turkmen Gas	Ahal Region	High quality gasoline (600,000 tons / year)
Sulfuric Acid Production Plant	National Chemical Corporation Turkmenistan	Lebap Region	Sulfuric acid (500,000 tons / year)
Ammonia and Urea Fertilizer Production Plant	Turkmenistan State Chemical Company	Mary Region	Ammonia (400,000 tons / year) Urea (640,000 tons / year)

Source: Socio-economic Development Plan of the President of Turkmenistan for 2019-2025 and Interview Survey by the Study Team

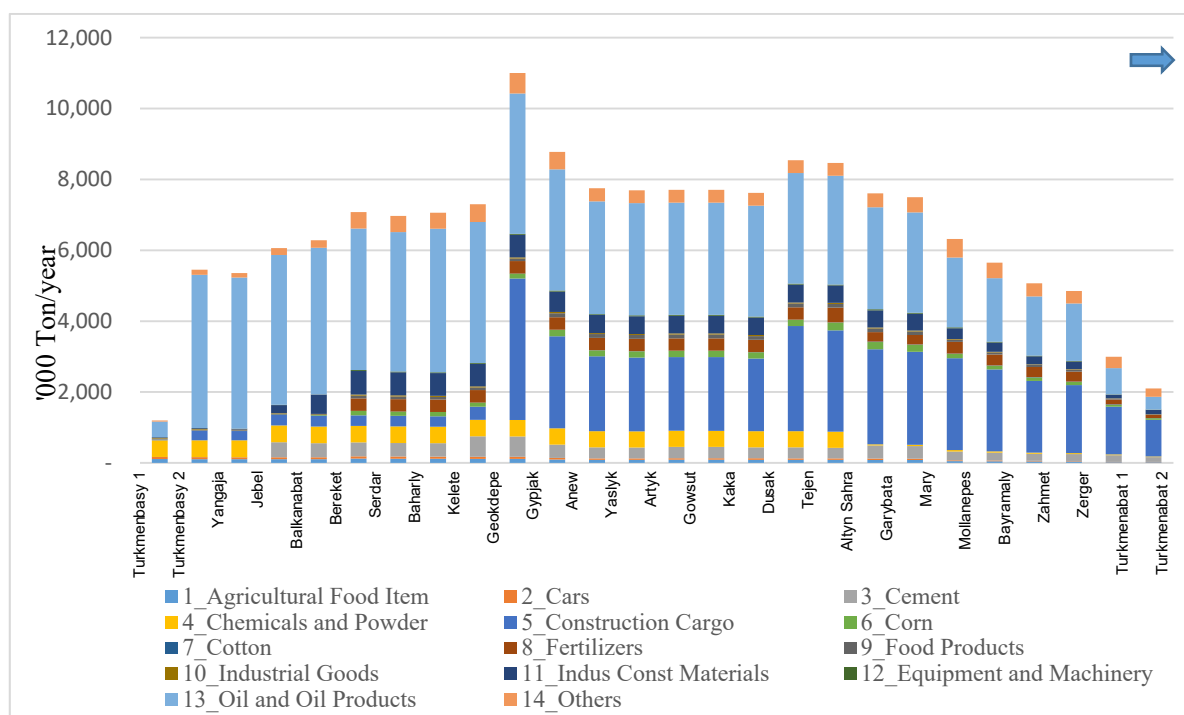
(5) Passenger Demand

In the case of passenger demand forecast, collected past passenger data and the number of daily trains are taken into consideration and forecasted using the future population growth rate. It is assumed that daytime trains (fast trains) will also be in operation. One day time train is considered to be composed of 10 cars and the average capacity of each car is 63 passengers. Daytime train loading factor is considered as 90% on average. It is assumed that about 35% of passengers take daytime trains, and, about 65% of passengers take night-time trains.

4.2.3 Result of Cargo and Passenger Demand Forecast

(1) Future Cargo Demand Forecast

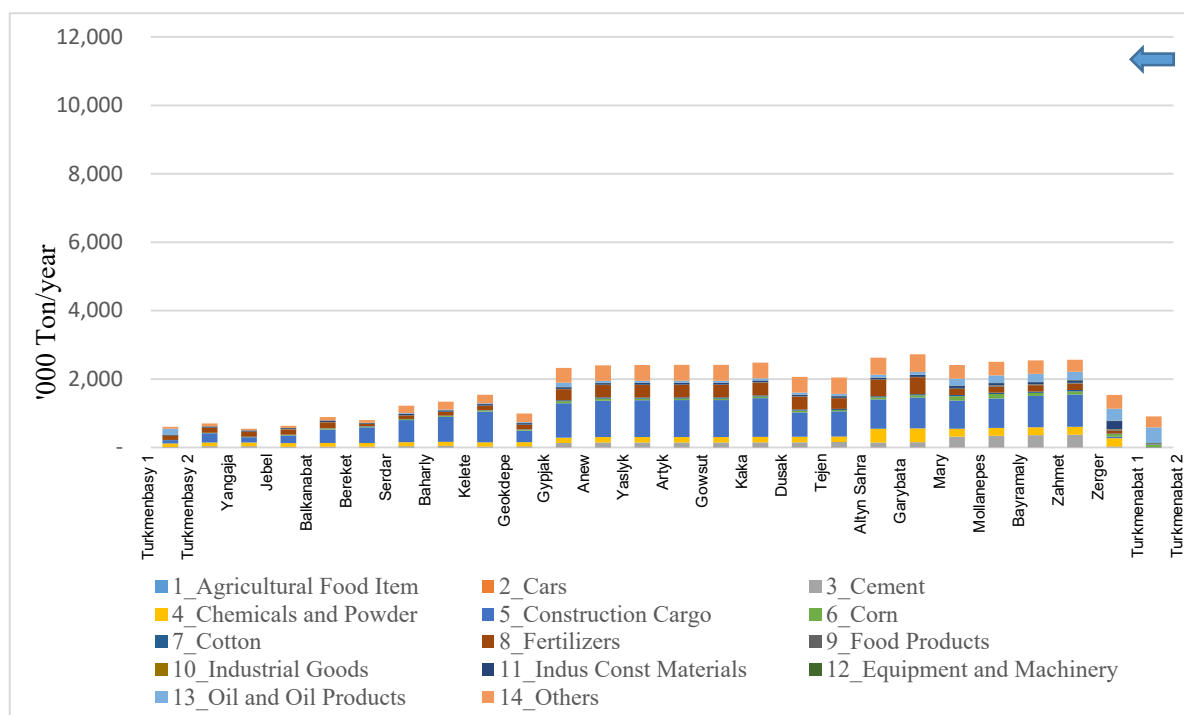
Based on the mentioned methodology, future cargo demand for the year of 2025, 2040 and 2055 are forecasted. The cargo demand is forecasted by domestic, export, import and transit. As it is mentioned earlier for domestic, export and import the same growth rate is considered for the future forecast, therefore, these data are summarized as non-transit cargo volume. Direction wise product based non-transit and transit cargo volume between Turkmenbasy to Turkmenabat in 2025 are shown in Figure 4-3 to Figure 4-6. In case of non-transit cargo, it is observed that the flow from Turkmenbasy to Turkmenabat is much higher than the opposite direction.



Source: Study Team

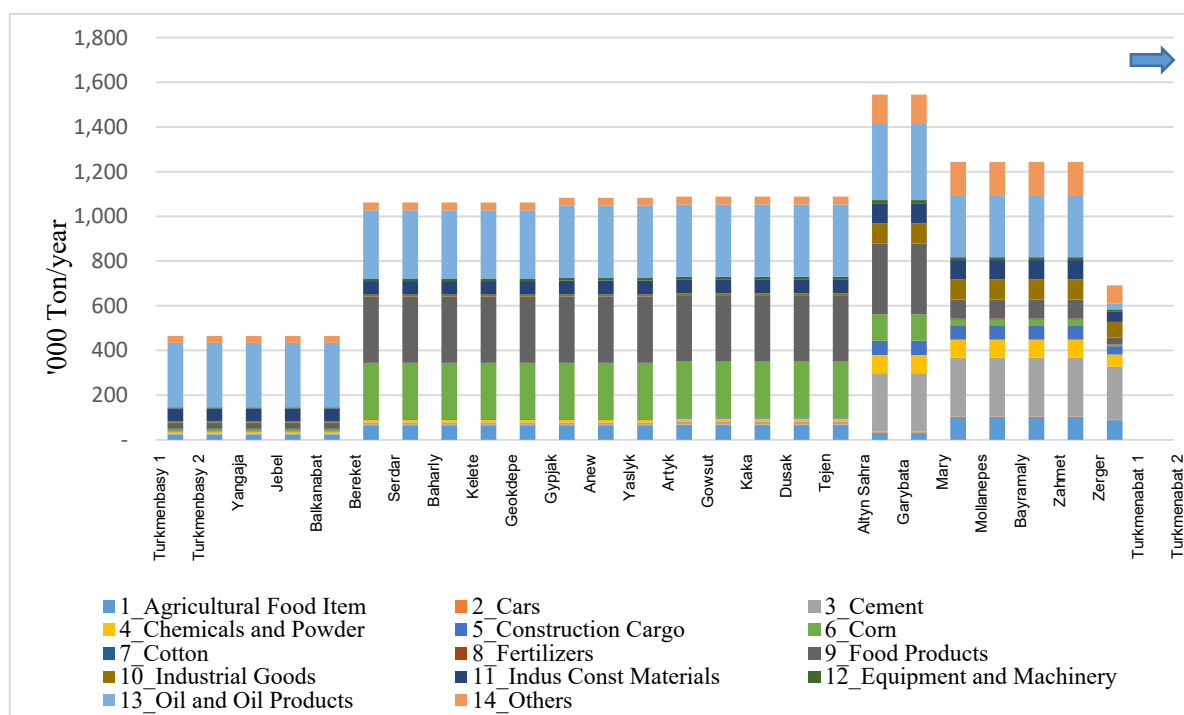
Figure 4-3 Product Wise Non-transit Cargo Demand of 2025 from Turkmenbasy to Turkmenabat

As it is shown in Figure 4-3, oil products (from Turkmenbasy 2 Sstation) and construction cargo (from Geokdepe Sstation) are transported in large volume from Turkmenbasy to Turkmenabat. On the other hand, from Turkmenabat to Turkmenbasy, construction material cargos are the main transportation item.



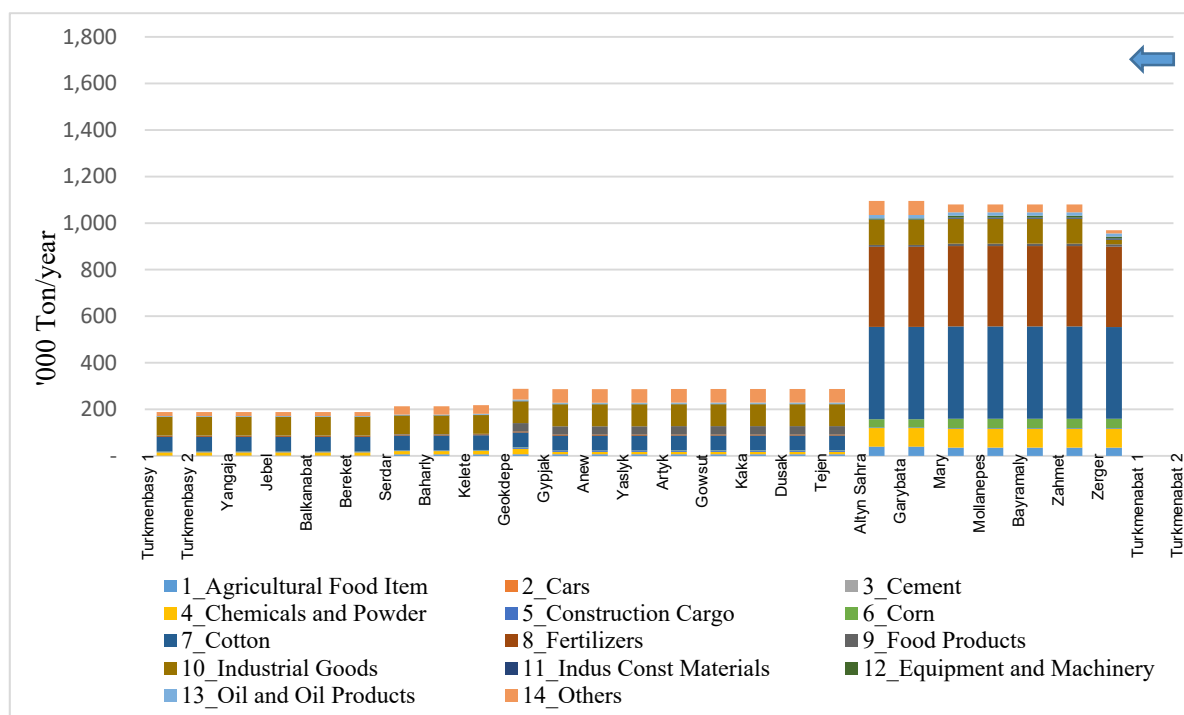
Source: Study Team

Figure 4-4 Product Wise Non-transit Cargo Demand of 2025 from Turkmenabat to Turkmenbasy



Source: Study Team

Figure 4-5 Product Wise Transit Cargo Demand of 2025 from Turkmenbasy to Turkmenabat



Source: Study Team

Figure 4-6 Product Wise Transit Cargo Demand of 2025 from Turkmenabat to Turkmenbasy

Future forecasted cargo volume of 2040 and 2055 between Turkmenbasy and Turkmenabat for transit and non-transit are described in Table 4-4.

Table 4-4 Cargo Demand Forecast between Turkmenbasy and Turkmenabat ('000 Ton/year)

Section	2040				2055			
	Transit		Non-transit		Transit		Non-transit	
	Up	Down	Up	Down	Up	Down	Up	Down
Turkmenbasy 1 - Turkmenbasy 2	798	323	2,020	1,023	1,369	555	3,406	1,723
Turkmenbasy 2 - Yangaja	798	323	9,187	1,188	1,369	555	15,485	2,002
Yangaja - Jebel	798	323	9,029	930	1,369	555	15,219	1,567
Jebel - Balkanabat	798	323	10,220	1,067	1,369	555	17,226	1,799
Balkanabat - Bereket	798	323	10,590	1,499	1,369	555	17,850	2,527
Bereket - Serdar	1,823	323	11,928	1,351	3,128	555	20,104	2,278
Serdar - Baharly	1,823	365	11,747	2,062	3,128	627	19,800	3,475
Baharly - Kelete	1,823	365	11,896	2,255	3,128	627	20,050	3,800
Kelete - Geokdepe	1,823	374	12,304	2,596	3,128	642	20,738	4,375
Geokdepe - Gypjak	1,823	495	18,542	1,675	3,128	849	31,253	2,823
Gypjak - Anew	1,859	493	14,789	3,922	3,191	846	24,927	6,610
Anew - Yaslyk	1,859	493	13,061	4,052	3,191	846	22,014	6,829
Yaslyk - Artyk	1,859	493	12,963	4,065	3,191	846	21,849	6,851
Artyk - Gowsut	1,869	494	12,984	4,068	3,207	847	21,885	6,857
Gowsut - Kaka	1,869	494	12,984	4,068	3,207	847	21,884	6,857
Kaka - Dusak	1,869	494	12,842	4,181	3,207	847	21,645	7,047
Dusak - Tejen	1,869	494	14,393	3,482	3,207	847	24,260	5,868
Tejen - Altyn Sahra	1,869	494	14,263	3,451	3,207	847	24,041	5,816
Altyn Sahra - Garybata	2,652	1,880	12,817	4,429	4,552	3,227	21,603	7,466
Garybata - Mary	2,652	1,880	12,634	4,591	4,552	3,227	21,295	7,738
Mary - Mollanepes	2,134	1,854	10,654	4,060	3,663	3,183	17,956	6,844
Mollanepes - Bayramaly	2,134	1,854	9,522	4,221	3,663	3,183	16,050	7,114
Bayramaly - Zahmet	2,134	1,854	8,546	4,290	3,663	3,183	14,404	7,231
Zahmet - Zerger	2,134	1,854	8,177	4,326	3,663	3,183	13,782	7,292
Zerger - Turkmenabat 1	1,186	1,664	5,047	2,591	2,035	2,856	8,507	4,367
Turkmenabat 1 - Turkmenabat 2	-	-	3,541	1,530	-	-	5,968	2,578

Source: Study Team

Note: Up = From Turkmenbasy to Turkmenabat ; Down = From Turkmenabat to Turkmenbasy

The highest cargo demand has been observed from Geokdepe (close to Ashgabat) to Mary.

(2) Future Passenger Demand Forecast

Future passenger demand from Turkmenbasy to Turkmenabat in 2025, 2040 and 2055 are estimated as shown in Table 4-5 major section wise. Out of 3 sections, Passenger demand in Ashgabat – Mary section is the highest in 2025, where 3,157,000 passengers will travel yearly.

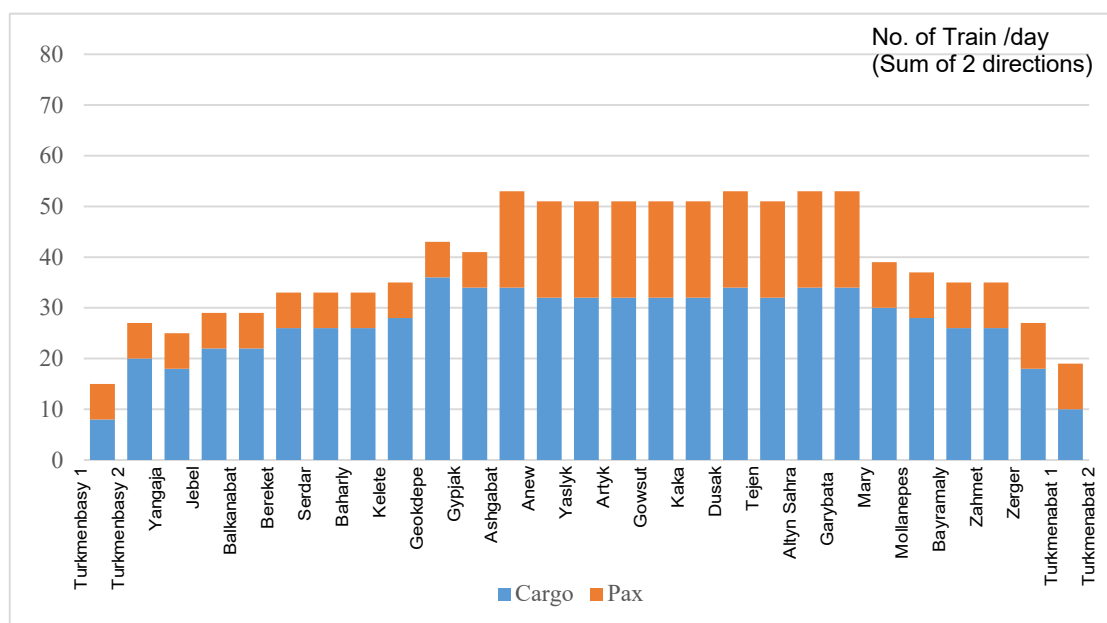
Table 4-5 Future Passenger Demand Forecast between Turkmenbasy and Turkmenabat ('000 pax)

	2025			2040			2055		
Section	Night Train	Day Train	Sub-Total	Night Train	Day Train	Sub-Total	Night Train	Day Train	Sub-Total
Turkmenbasy-Ashgabat	714	414	1,127	980	414	1,394	1,101	621	1,722
Ashgabat-Mary	1,915	1,242	3,157	2,661	1,242	3,903	3,166	1,656	4,821
Mary-Turkmenabat	957	621	1,578	1,331	621	1,951	1,583	828	2,411

Source: Study Team

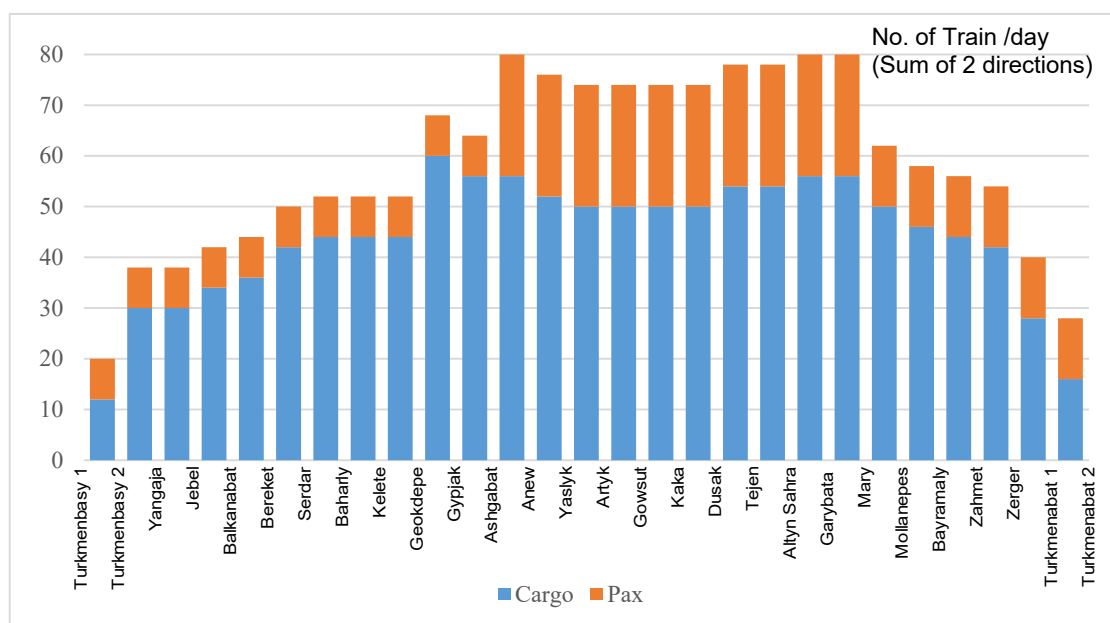
4.2.4 Train Operation

Based on the results of the demand forecasting, an operation plan is formulated and the number of required trains in the future between Turkmenbasy and Turkmenabat was calculated (Ref Figure 4-7). The section with the highest number of trains operated is from Ashgabat to Mary. By adding up both cargo and passenger trains it is found that a total of 52 trains are needed in 2040 and 78 trains are needed in 2055. In particular, the number of trains operating nearby Ashgabat and Mary is increasing. The following shows the number of trains needed to operate on the main line. In addition to this, there are trains for depots and workshops, so it is expected that the number of trains operating near Ashgabat and Mary will increase further. For this reason, considering the operation of these trains, it is desirable to have a double track in 2055 for this section.



Source: Study Team

Figure 4-7 Required Number of Trains in 2040 from Turkmenbasy to Turkmenabat

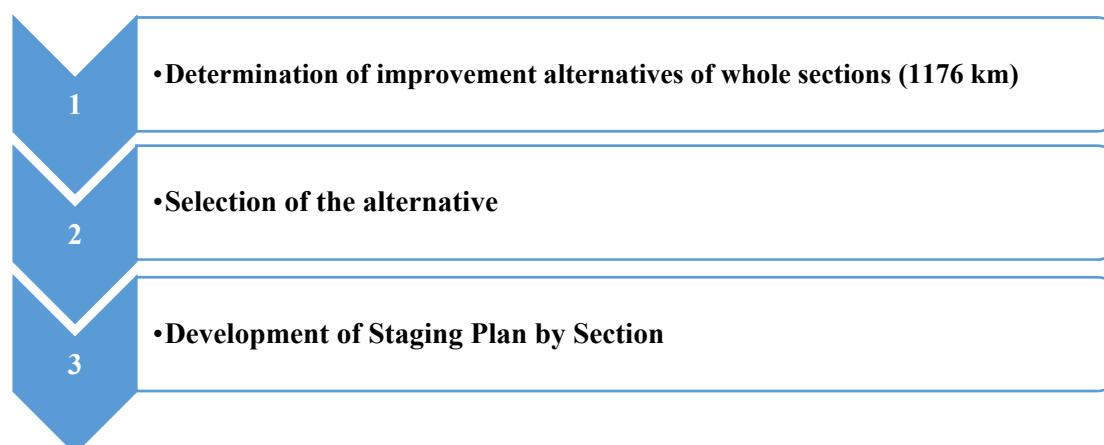


Source: Study Team

Figure 4-8 Required Number of Trains in 2055 from Turkmenbasy to Turkmenabat

4.3 Overview of Alternatives for Modernization

Alternatives for the projects have been selected based on the flow chart showed in Figure 4-9. At first, improvement alternatives for all the sections are selected and then alternative options are selected. After that, stage wise development plans by section are considered.



Source: Study Team

Figure 4-9 Flow of Alternative Selection

4.3.1 Items of the Alternative Options

The items of improvement works are shown in Table 4-6.

Table 4-6 Items of Improvements

Item	Speed	Capacity
Electrification (improvement of efficiency)	higher acceleration	
Signal improvement	+	+
Track improvement for 160km/h operation**	+++	+
Double tracking***	++ (avoid train meet)	+++

*including minor signal improvement for improved civil structures

**maximum speed

***including major improvement of signalling

+ limited increase

++ moderate increase

+++ significant increase

Source: Study Team

In consideration of the items 4 alternatives are considered which are described in Table 4-7.

Table 4-7 Alternatives of Modernization

Altern ative	Electrification	Rolling stock & Depot	Civil Works	Signal *	Maximum Speed	Capacity
A	✓	RS for 120 km/h	-	✓	Same as current	Same as current
B	✓	RS for 120 km/h	Minor Works	✓	120 km/h (Original design speed)	+
C	✓	RS for 160 km/h	Major Works	✓	160 km/h (passenger) 100 km/h (freight)	+
D	✓	RS for 160 km/h	Major Works for Double Tracking	✓	160 km/h (passenger) 100 km/h (freight)	+++

*Signalling and communication; Alt stands for alternative. RS stands for rolling stock.

Source: Study Team

Different items are considered for each of these alternatives, which are described as below

(1) Outline of Alternative A

1) Civil Works

- Procurement of 5 Multiple Tie Tamperers (MTTs) for repair of track irregularity and ballast supplement (These works need to be done in daily maintenance)
- Replacing of fastenings for electrification and sleepers
- Replacing of rail bond for electrification
- Construction of a new depot for electric locomotives
- Temporary access road for electrification works

2) Electrification

- Transmission lines
- Construction of substations (14 substations)
- Installation of electricity distribution facilities
- Installation of electric circuit facilities (overhead catenary)

3) Rolling stock

- Electric locomotives & EMUs

4) Signalling

- Interlocking device
- Programmed Route Control (PRC)
- Track circuit device (Train detection)
- Automatic train protection (ATP)
- Level crossing protection facilities
- Signal device and etc.

5) Telecommunications

- Transmission channels and facilities (Main fibre optic cables)
- Command telephone system
- Train radio system
- Weather monitoring (Rain, Seismometer, Wind)
- CCTV system

(2) Outline of Alternative B

1) All Components of Alternative A

2) Civil Works

- Replacement of Roadbed and Ballast for Mud-pumping (assuming 10% of tracks)
- Damaged Rail Replacement (assuming 10% of tracks)
- Roadbed and Track works for Siding (if required based on analysis on train operation)
- Fence

(3) Outline of Alternative C

1) All Components of Alternative B

2) Civil Works

- Track Improvement for 160km/h (Resetting of Transition Curve and Cant)
- Installation of Level Crossing Gate (assuming 50% of level crossings)

3) Signalling and Electrification for 160km/h operation

(4) Outline of Alternative D

1) All Components of Alternative C (except for siding)

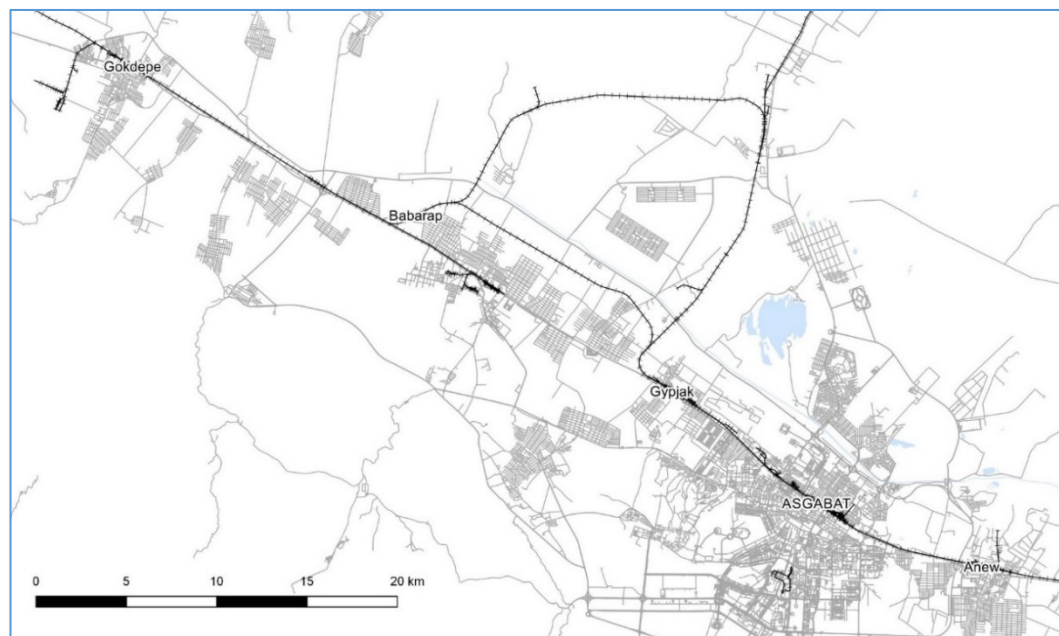
2) Civil Works

- New bridge (8.4m Width) construction for double track (7.9km)
- New Pipe Culvert for Drainage (φ630, 242km)
- Embankment for New Track (H=1.5m, 1,177km)
- New Track Works (1,177km)
- New Level Crossing for new track (1,177km)
- Procurement of 13 Multiple Tie Tamper
- Temporary Access Road for electrification works and double track works (1,177 km × W6m)

3) Signalling and Electrification for 160km/h operation and double track

(5) Option 1 and 2

In addition to the above-mentioned alternatives two more options are also considered under this project. Both are double tracking of certain sections. One is Geokdepe – Ashgabat – Anew, which is about 80km long. Another is Garybata – Mary – Bayramaly, which is 63km.



Source: Study Team

Figure 4-10 Target Section of Geokdepe – Ashgabat – Anew



Source: Study Team

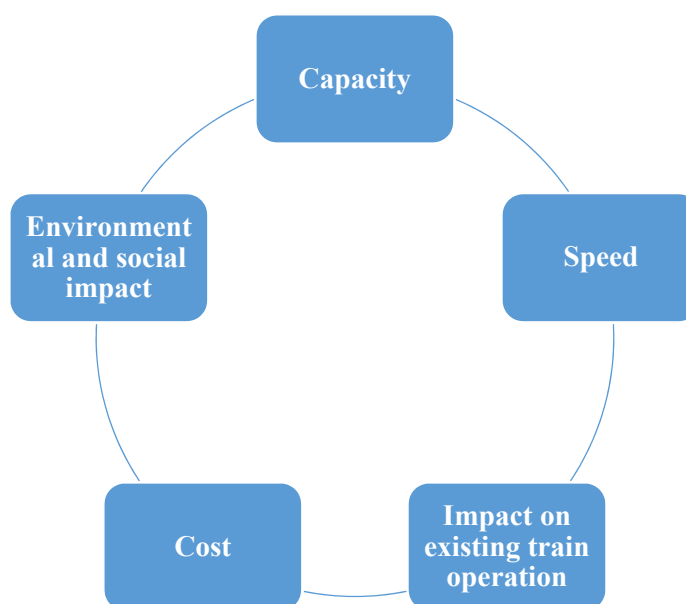
Figure 4-11 Target Section of Garybata – Mary – Bayramaly

4.3.2 Comparison of Alternatives

Comparison the alternatives are described in this section.

(1) Comparison Items

Items up for consideration Considered items which are used for comparing the alternatives are shown in Figure 4-12.



Source: Study Team

Figure 4-12 Comparison Items for Alternative Selection

(2) Capacity

Descriptive capacity analysis and scores for each alternative are shown in Table 4-8.

Table 4-8 Score and Description of Capacity

Alternative	Score	Description
Zero-option	0	There is no change of track capacity.
A	+	Slight increase of track capacity is expected due to signal improvement.
B	+	Slight increase of track capacity is expected due to signal improvement.
B+ Option 1&2	++	Moderate increase of track capacity is expected due to short double track section and signal improvement.
C	+	Slight increase of track capacity is expected due to signal improvement and addition of siding facilities.
D	+++	Significant increase of track capacity is expected due to double track and signal improvement.

+++ : significant positive impact
 ++ : moderate positive impact
 + : limited positive impact
 0 : no impact / offset of positive and negative impact
 - : limited negative impact
 -- : moderate negative impact
 --- : significant negative impact
 Source: Study Team

(3) Speed

Speed analysis scores for each alternatives are shown in Table 4-9.

Table 4-9 Score and Description of Speed

Alternative	Score	Max Speed	Description
Zero-option	0	80km/h	There is no change of train operation speed.
A	0	80km/h	There is no change of train operation speed.
B	++	120km/h (100km/h)	Improvement of train operation speed to the original design speed
B+ Option 1&2	++	120km/h (100km/h)	Improvement of train operation speed to the original design speed
C	+++	160km/h (100km/h)	Significant Improvement of train operation speed for 160km/h operation
D	+++	160km/h (100km/h)	Significant Improvement of train operation speed for 160km/h operation

Source: Study Team

(4) Impact on Railway Operation

Impact of work projectss on the existing train operation isare considered under this item and is shown in Table 4-10.

Table 4-10 Items for Impact on Railway Operation

Items of Improvement	Required time for stopping operation
Replacement of Roadbed and Ballast for Mud-pumping	About 4 hours per one location
Damaged Rail Replacement	About 75m-100m per 3 hours
Roadbed and Track works for Siding	Only working hours to install the turnout (About 3-4 hours per one turnout-8#)
Track Improvement for 160km/h (Transition Curve, Cant)	A few days per one curve
Installation of Level Crossing Gate	No need to stop the train operation
New Level Crossing for new track	No need to stop the train operation

Source: Study Team

Precondition of temporary access road construction is adopted and the train operation timetable is revised for the works for 3 hours every day.

Table 4-11 Score and Description for Impact on Railway Operation

Alternative	Score	Description
Zero-option	0	There is no change of track capacity.
A	-	Stop of train operation for about 3 hours almost every day is required during electrification works.
B	-	Stop of train operation for about 3 hours almost every day is required during civil and electrification works.
B+ Option 1&2	-	Stop of train operation for about 3 hours almost every day is required during civil and electrification works.
C	---	Stop of train operation for about 3 hours almost every day is required during civil and electrification works. In addition, stop of train operation for a few days is required for improvement of each curvature.
D	-	Stop of train operation for about 3 hours is required during civil works of switches of the existing track.

Source: Study Team

(5) Cost

1) Preconditions of Project Cost Estimation

- Project cost estimation was calculated based on the unit cost of each item (civil works, depot, signalling and telecommunication, rolling stock, OHC, transmission lines and etc.)
- Unit cost of civil works, depot, signalling and telecommunication, rolling stock and transmission lines was set based on similar projects and corrected in accordance with Turkmenistan conditions.
- Cost for bridge improvement and replacement was not considered according to the limited site surveys of this study. However, since it was not possible to conduct a site survey for all bridges, there is a possibility to have an increase in the cost for bridge improvement and replacement during the future supplemental survey or detailed design stage.
- Maintenance and repair for track irregularity and refilling of ballast should be conducted during the daily maintenance under Turkmenistan Railway Agency; therefore, the cost was not included under this study.
- Track length which requires the replacement of damaged rails and maintenance and repair for mud-pumping was assumed as 40% of the total track length according to the hearing with Turkmenistan Railway Agency.
- Average height for new embankment for double-tracking was assumed as 1.5 m.
- Unit cost of a transmission line was set based on the hearing with Turkish construction company.
- Cost for transmission line was considered assuming the 110kV connecting transmission line method.
- Contingency of 5% was considered for each field.

- Engineering cost was set as 4% of the subtotal cost including contingency and contingency of 5% was considered.
- Taxes such as customs (VAT) were not considered in this project cost estimation due to tax exemption depending on the type of business.
- Land cost was not considered since the lands along railway alignment in urban and suburban areas are secured for ROW widening.

2) Estimated Cost of Each Alternative

Table 4-12 Estimated Cost of Each Alternative

[Unit: Mil. USD]

Item	Alt. A	Alt. B	Alt. B +	Alt. C	Alt. D
Substation	312	312	312	312	422
Transmission Lines	287	287	287	287	287
Electric Power Command Centre	11	11	11	11	14
Rolling Stocks (inclusive of freight	1,481	1,481	1,481	1,481	1,481
Renovation of Depot (inclusive of	309	309	309	309	309
Signalling	918	918	1,106	1,222	1,860
Telecommunication	847	847	1,022	847	1,439
OHC	192	192	231	192	320
Civil Works	505	1,089	1,421	1,112	3,253
Subtotal	4,862	5,446	6,180	5,773	9,385
Contingency (5%)	243	272	309	289	469
Engineering Cost	214	240	273	255	414
Total	5,319	5,958	6,762	6,317	10,268

Source: Study Team

The cost analysis and score for each of the alternatives are shown in Table 4-13.

Table 4-13 Score and Description for Cost

Alternative	Score	Cost (M USD)
Zero-option	0	0
A	-	5,319
B	-	5,958
B+ Option 1&2	-	6,762
C	-	6,317
D	---	10,268

*1 Tax excluded; engineering cost included; contingency included

*2 Assumptions of cost estimates are described in the reference

Source: Study Team

(6) Environmental and Social Impact

Precondition of no need land acquisition and involuntary resettlement when double tracking, siding and electrification are installed are considered for the scoring of environmental and social impact.

Table 4-14 Score and Description for Environmental and Social Impact

Alternative	Score	Description based on Zero-option
Zero-option	0	No change. But cannot respond to the future demand.
A	+	Reduction of emission diesel gas by electrification. (+) (Common description from A to D)
B	++	Improvement of social infrastructure. (+)
B+ Option 1&2	++	Need additional soil for embankment section for double track. (-) Further Improvement of social infrastructure. (++)
C	+	Deterioration of noise and vibration level, and safe crossing for livestock and local people due to increased speed of the train. (--) Further improvement of social infrastructure. (++)
D	+	Deterioration of noise and vibration level, and safe crossing for livestock and local people due to increased speed of the train. (--) Need additional soil for the embankment section for double track. (-) Much further improvement of social infrastructure. (+++)

Source: Study Team

(7) Overall Evaluation

The overall evaluations based on each criteria are described in Table 4-15

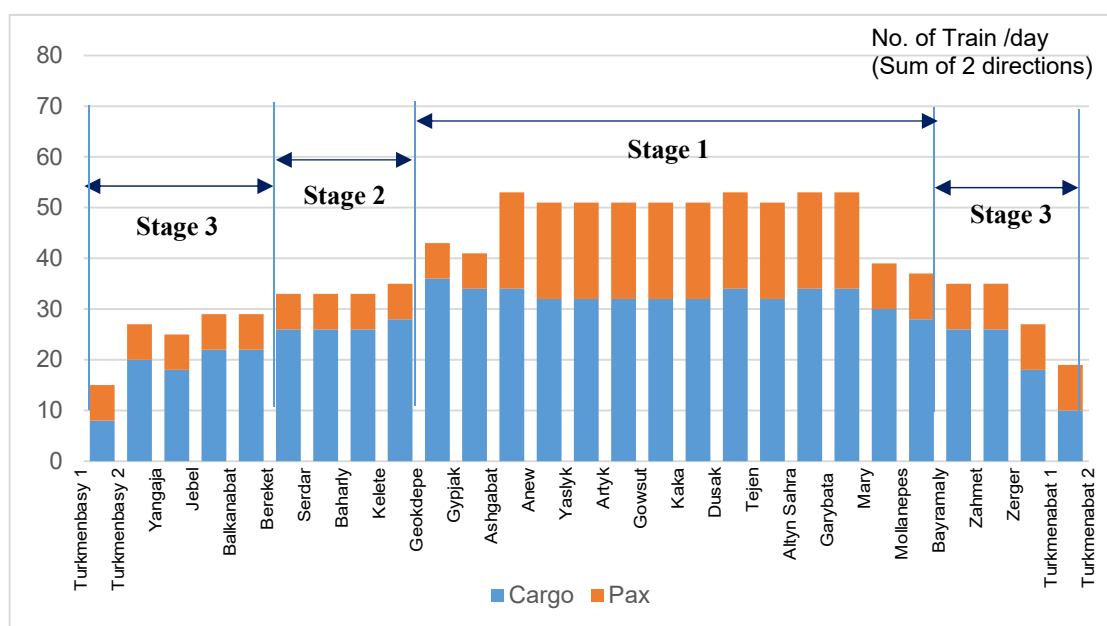
Table 4-15 Overall Evaluation of the Alternatives

Alternative	Capacity	Speed	Existing Train Operation	Cost	Env. & Social	Total
Zero-option	0	0	0	0	0	0
A	+	0	-	-	+	+-
B	+	++	-	-	++	+
B + Option 1&2	++	++	-	-	++	++
C	+	+++	---	-	+	+-
D	+++	+++	-	---	+	++

Source: Study Team

4.3.3 Staged Development Plan

Based on the number of trains required to operate in the future, the selection of priority sections for improvement is selected. In order to increase the capacity and speed effectively, the first stage of improvement is selected as ‘Alternative B’ together with ‘Option 1 & 2’, which means the section between Geokdepe – Ashgabat – Anew – Garybata – Mary – Bayramaly. Development between Bereket and Geokdepe is selected as the second stage and the rest (between Turkmenbasy and Bereket and between Mary and Turkmenabat) is selected for the third stage.

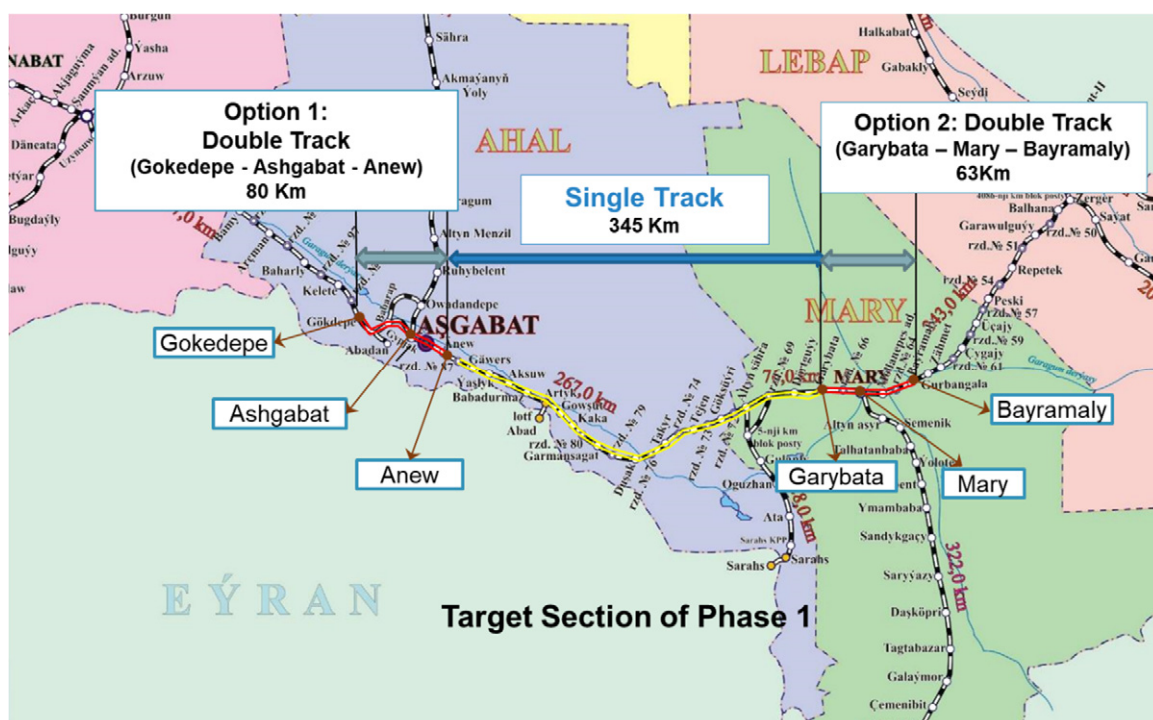


Source: Study Team

Figure 4-13 Considered of Divided Sections for the Study Route

4.4 First Stage of Modernization Plan

The items for the development of the Geokdepe – Ashgabat – Mary - Bayramaly section are described as the first stage modernization plan. In the first stage, Geokdepe – Ashgabat – Mary - Bayramaly will be electrified and modernized in consideration of speeding up. In this section, about 80 km along Geokdepe – Ashgabat -Anew and about 63 km along Garybata – Mary - Bayramaly will be converted into double track. Modernization work such as electrification and civil works for speeding up will be carried out on the existing single track between Anew and Garybata.



Source: Study Team

Figure 4-14 First-Stage Modernization Plan

4.4.1 Operation Plan

Train operation plan between Geokdepe and Bayramaly is formulated in this part. The whole section is divided into several sub-sections: Geokdepe - Ashgabat, Ashgabat - Dusak, Dusak - Mary, Mary - Bayramaly and the number of trains that can be operated in each section is estimated. The calculation method of the operation plan is as follows. The speed mentioned in this part is not the maximum speed, but the average speed of the section.

- The distance between the stations is estimated in km based on the RA website. The number of intermediate locations that can be replaced is estimated based on the railway network line diagram received from RA.
- In the case of distance which is not specified between stations or rail junction, it is assumed that intermediate locations where a train can side is situated at equal interval. Then based on the distance between stations, the distance between the station and those intermediate locations are estimated. (e.g. in case of the distance between two stations being 40 km and the number of intermediate locations being only one, the distance of single tracks that cannot be replaced is estimated to be 20 km.)
- By using the operating hours of that section, the average speed was calculated. For example, the average speed of 46 km/h is found based on the time required between Ashgabat and Mary and distance.

- Regarding the improvement of speed when electrified, the speed ratio in Japan is taken as an example to compare between the diesel locomotive and electric locomotive and as a result an average speed of 52km/h is used which is 14% more (As example, the required time between Nagoya and Inazawa is 12 minutes 15 seconds for a diesel locomotive and 10 minutes 30 seconds for an electric locomotive).
- The number of daily trains that can be operated is calculated assuming that the train will operate for 20 hours excluding 4 hours of maintenance time.
- The operation pattern is divided into pattern 1 (an alternate operation of an inbound and an outbound train) and pattern 2 (an alternate operation of two inbound and two outbound trains). Based on this, for a section of 26 mins-distance of single track Pattern 1 can accommodate 46 set of trains in 20 hours (20 hours / 26 minutes). In the case of pattern 2, it is assumed that the continuation time is 5 minutes (total required time for the block section of 1.5 km + extra time). This makes the possible train operation as 77 sets in 20 hours [20 hours / (26 + 5 minutes) x 2].
- The number of trains that can be operated in each of the four sections are calculated.
- The following cases are considered to calculate the expected number of train operations

Cargo train: Estimated demand / (4200 tons x 2)

Passenger train: Estimated demand

- The number of trains (total of cargo and passenger train) can be operated or not is confirmed.
 - The following cases are considered to calculate the expected number of train operations
- Case 1: Assuming the operating speed for capacity increase when speed is improved
- Case 2: Assuming how much the operating speed needs to be improved, if the track is double-tracked or the number of siding points is increased to increase the capacity.

The results of the consideration are as follows.

- Pattern 1 seems to be able to handle the estimated demand up to 2025, but the track capacity between Ashgabat – Dusak is expected to be insufficient by 2040 (the capacity is 48 train sets against the demand of 53 trains). Thus, some actions need to be taken such as electrification, speed up, switching facilities improvement and doubling the track at certain section. The section of Geokdepe – Mary will also be affected by insufficient capacity within 2055, which require actions to be taken.
- If the operation Pattern 2 is chosen, the current facilities will be sufficient until 2055. However, since all trains are assumed to be as 4200 ton and return to the main line, the number of trains will increase by product-specific cargo formation and thus, station facilities such as passing lines need to be increased. It is also necessary to consider reducing the total number of trains by combining the Eastbound and Westbound trains and increase the number of round trips by using containers.

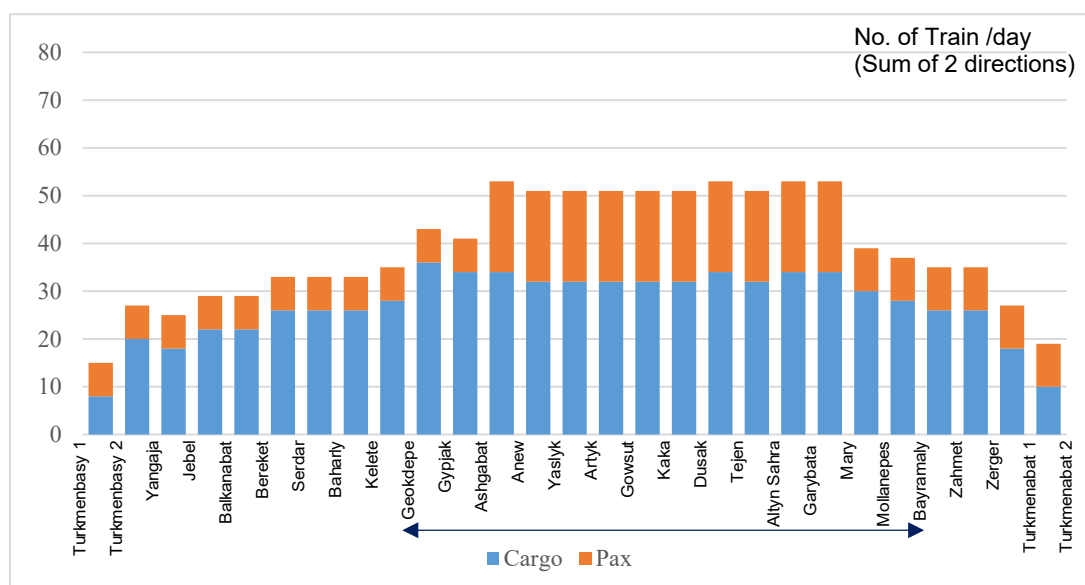
- Unless the speed is increased to 110 km/h for Pattern 1 and 75 km/h for Pattern 2, the number of possible operable trains will be less than the demand. For certain sections, if the speed is not achieved up to 90 km/h for Pattern 1 and 60 km/h for Pattern 2, the number of operable trains will be less than the demand, even if partial double track or siding is realized.
- A precondition is proposed as double tracking of the section Geokdepe – Ashgabat - Anew and Garybata – Mary – Bayramaly; however, if only the operation on the main line is assumed, this might not be highly necessary. However, the estimation of the operation of the main line does not take into consideration the trains in depots, workshops and unused cargo trains. As these facilities are located around Ashgabat and Mary, considering these facts, double tracking of Geokdepe – Ashgabat - Anew and Garybata – Mary - Bayramaly is proposed. In the future a detailed calculation based on the unused trains, spare trains, etc., will be required in the F/S.

The number of electric locomotives required when electrifying between Geokdepe and Bayramaly is estimated and the required trains for 2027, 2040 and 2055 are shown in Table 4-16.

**Table 4-16 Required Number of Electric Locomotive in the Target Section for First Stage
Modernization**

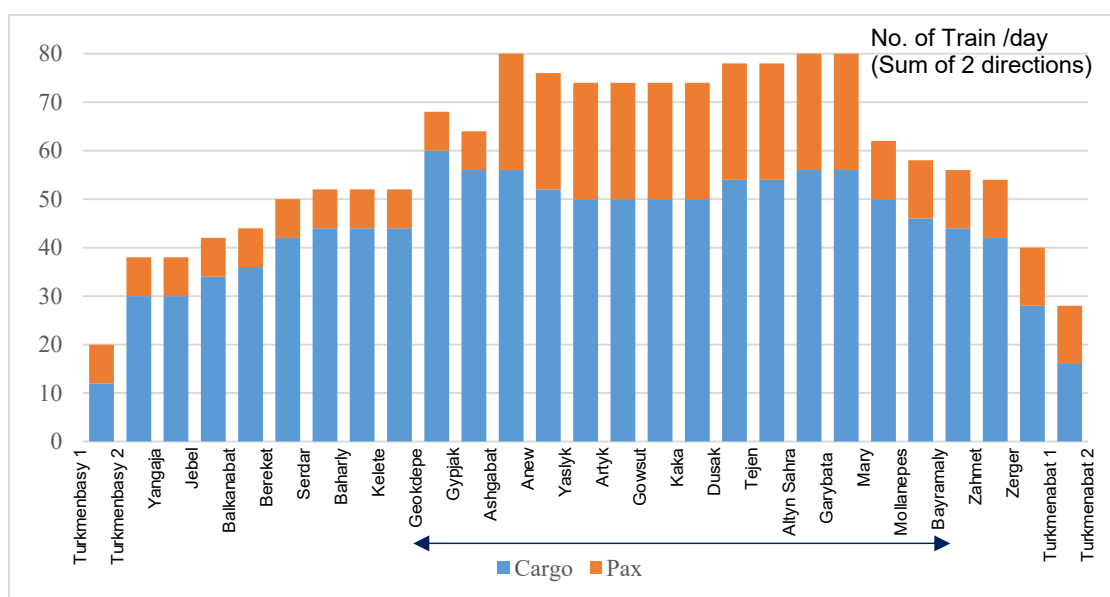
Year	In Use	Spare	Total
2027	40	5	45
2040	52	5	57
2055	78	8	85

Source: Study Team



Source: Study Team

Figure 4-15 Required Number of Trains in the Target Section in 2040



Source: Study Team

Figure 4-16 Required Number of Trains in the Target Section in 2055

The calculation method is as follows.

- Based on the predicted number train operation diagram for the future is prepared.
- 3 hours waiting time (inspection No 2 required time) is preserved to ensure locomotive inspection.
- The number of required locomotives are calculated from the locomotive operation schedule.
- The concept of preparatory inspection is as follows.
 - 1) The daily travel distance from locomotive operation schedule is calculated.
 - 2) The number of days corresponding to Inspection No 3, Repair work 1 and 3, Major Repair work are calculated
 - 3) The required number of train per day (number of withdrawals) for each inspection is calculated.
 - 4) The number of spare trains is calculated.
 - 5) Calculation example in case of 400km is as follows.

Inspection 3: 0.02 train is required per day; to perform a daily inspection in every 50 days

Repair work 1: 0.01 train is required per day; 2 days are needed in every 150 days

Repair work 3: 0.02 train is required per day; 14 days are needed per 600 days

Major Repair work: 0.05 train is required per day; 90 days are needed (same as to Japan) for every 1800 days

Therefore, theoretically, the total number of repairs is 0.1 train per day.

4.4.2 Plan for Civil Structures

(1) Track Maintenance for Existing Line

Although Turkmenistan railway was planned and built for a maximum design speed of 120 km/h, the current condition shows that the design speed cannot be reached. This can be attributed to track irregularity induced by insufficient track maintenance. Therefore, at the first stage of modernization plan, maintenance and renewal of track are proposed as below to enable a safety travel at a maximum speed of 120 km/h for passenger trains and 100 km/h for freight trains.

1) Maintenance and Repair of Roadbed due to Mud-Pumping

As mentioned in 3.5.2, locations where mud-pumping induced by poor drainage were confirmed here and there on site. In the case that mud-pumping of road occurs, functions of ballast such as to provide moderate elasticity, to support roadbed and to distribute load will deteriorate. Therefore, it is necessary to take countermeasures against mud-pumping at the said locations. Since countermeasures differ depending on the cause of mud-pumping, it is necessary to conduct a detailed soil investigation regarding soil condition and ground water to determine the countermeasures at the detailed design stage. As a reference, Figure 4-17 shows the flow for selection of mud-pumping Countermeasures.

without affecting current train operation, it is necessary to have adequate and expeditious work within the current interval between train operations of approximately 4 hours. Therefore, it is preferred to have MTT (Figure 4-18) for the maintenance and repair work which can conduct tapping (ballast tamping), levelling (rail level adjustment) and lining (vertical and horizontal alignment correction) all at once. However, there are only 3 MTTs owned by Turkmenistan Railway.

In view of safety, maintenance and repair for track irregularity and refilling of ballast should be conducted during daily maintenance under the Turkmenistan Railway Agency. Therefore, although the cost for MTT procurement is not under the scope of this Study, it is proposed to have 5 additional MTTs to perform adequate and expeditious maintenance work.



Source: Web Site of Itake-Shoji

Figure 4-18 Multiple Tie Tamper (MTT)

3) Replacement of Damaged Rail

As mentioned in 3.5.2, damaged rail ends at expansion joint sections are confirmed here and there on site, and replacement of 65 kg Rail is required at the said locations. According to the hearing with Turkmenistan Railway Agency, it is considered that approximately 40% of the existing rail needs to be replaced. However, it is necessary to conduct site surveys of the target section to review whether the replacement of the rail is required in the future supplementary survey or detailed design stage.

(2) Replacement of Rail Bond for Electrification

The rail bond is to electrically connect rails at the joint between rails to constitute the current driving circuit and signal circuit. As shown in Figure 4-19 , rail bond with small diameter for the constitution of the signal circuit was currently adopted in Turkmenistan. Therefore, it is necessary to replace the rail bond with a large diameter in order to prepare the current driving circuit for electrification.



Source: Study Team

Figure 4-19 Current Rail Bond in Turkmenistan

(3) Installation of Entry Prevention Fence

As mentioned in 3.5.2, it was confirmed that in some sections along the railway in suburbs, a low wire fence was installed to prevent camels from entering the railway ROW. In addition, there are some places where broken wire and fallen post were confirmed as well, which enable easy entry to the railway ROW. While a passenger train is operating at a speed of 120 km/h, contact and collisions between vehicles and people or animals will cause catastrophic disasters. Therefore, it is proposed to install a mesh fence (Figure 4-20) with a height of approximately 1.5 m within all target sections to prevent not only animals but also people from entering into the railway ROW.



Source: <https://field-saver.com/blog/?p=9891>

Figure 4-20 Mesh Fence

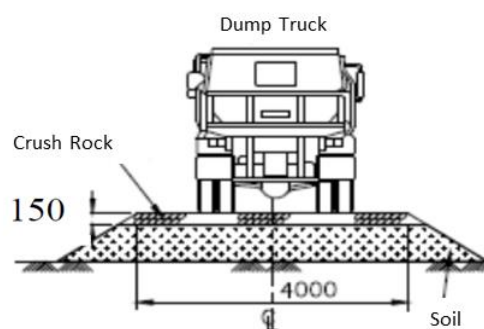
(4) Installation of Temporary Road for Construction

Basically, it is the intention to conduct the electrification of the existing single track while under current operation. Transportation of equipment such as electrified poles can be done by a road-rail vehicle using the existing track or a truck using a temporary road installed for construction. Considering construction cost only, it is desirable to have the transportation done by a road-rail vehicle using the existing track.

However, to meet the principle of keeping current operation of the existing single track, it is proposed to install a temporary road for construction beside the existing track as shown in Figure 4-21 in order to reduce the impact on train operation and shorten the construction period. In the case that a temporary road for construction is installed, since there is no need to reduce the number of train operations, it is unlikely that railway revenue will decrease during construction. This can be considered as a great advantage due to the high percentage in cargo of railway revenue in the target section of this study.



Source: <http://setodennews.sblo.jp>



Source: Study Team

Figure 4-21 Temporary Access Road

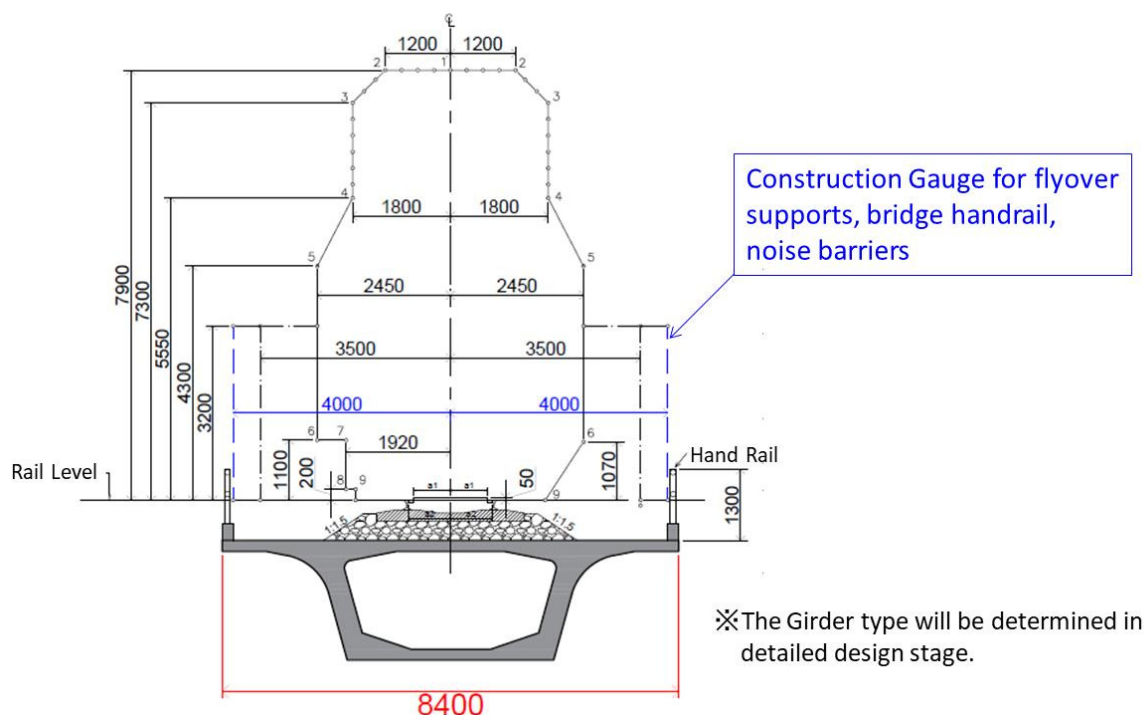
(5) Double-Tracking Work at the sections of Geokdepe - Anew (80 km) and Garybata - Bayramaly (63 km)

As mentioned in 0, it is desirable to conduct double-tracking from the first stage of modernization plan for the high demand sections of Geokdepe - Anew (80 km) and Garybata - Bayramaly (63 km). The following describes the civil works which are required for double-tracking.

1) Construction Work of New Bridge

At the sections of Geokdepe - Anew and Garybata - Bayramaly, construction of new single bridge in parallel with the existing bridge is planned for double-tracking. Within the same sections, there are 25 bridges between Geokdepe and Anew (total length of 269 m) and 23 bridges between Garybata and Bayramaly (total length of 473 m), therefore, it is assumed to construct a new bridge of the same scale with each existing bridge. In addition, based on the construction gauge for bridge handrail received from Turkmenistan Railway, it is considered to have a structure width of approximately 8.4 m (Figure 4-22).

It is necessary to determine the structure type and span appropriately based on the view point of construction method and economic efficiency at the detailed design stage.

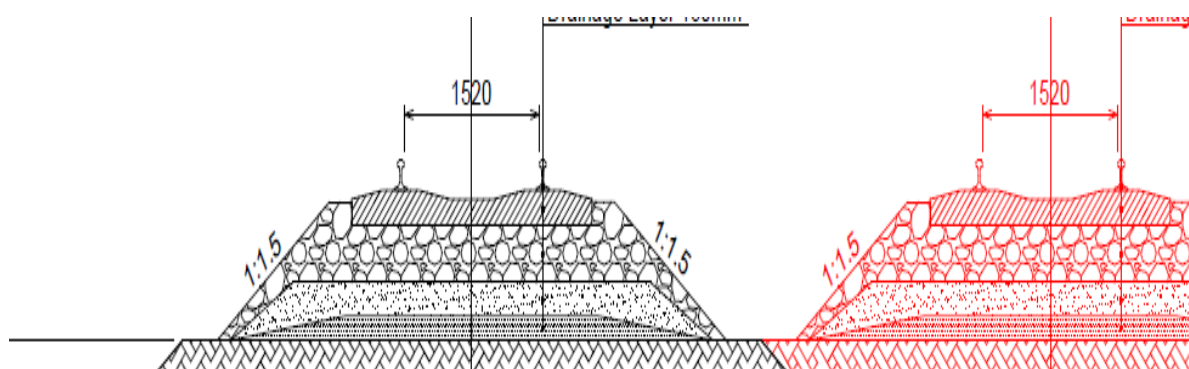


Source: Study Team

Figure 4-22 Structure Width of New Single-Bridge for Double Track (Tentative)

2) Embankment and Track Work

Construction of new single track in parallel with existing track is planned for double-tracking. It is necessary to determine the rail level for the new track based on the topography, flood level, etc., as currently it is assumed to have the same rail level with the existing track. Consequently, as shown in Figure 4-23, new track will be installed at the new embankment which will be widened from the existing embankment. In addition, a similar drainage culvert will be installed at the new embankment corresponding to the existing embankment.



Source: Study Team

Figure 4-23 New Embankment for Double Track

(6) Study on the Necessity of Curve Radius Improvement

Speed in a curve is determined by gauge, cant and curve radius. Although the speed increases as the curve radius increases, according to Japanese Railway Standard, it is desirable to secure the speed in a curve as approximately 80% or more of the design maximum speed considering construction cost, etc. At the first stage of the modernization plan, it is proposed to have a maximum speed of 120 km/h for passenger trains. To secure the speed in curves as approximately 80% of the maximum speed, a curve radius of approximately 500 m or more is required as shown in Table 4-17. As mentioned in 3.5.2, the minimum curve radius currently adopted between Turkmenabat - Ashgabat - Turkmenbasy is 504 m, therefore, it is concluded that there is no need for the improvement of curve radius as long as the maximum design speed is set as 120 km/h.

The current maximum speed of the section between Turkmenabat - Ashgabat - Turkmenbasy was designed as 120 km/h, therefore, it is considered that there is no need to change the cant and length of transition curves as well.

Table 4-17 Speed in Curve and Curve Radius (Reference)

	Speed in Curve
	96 km/h (80% of the maximum speed)
Required Curve Radius	Approximately 500 m
Numbers of Locations required Improvement of Curve Radius	N/A

Source: Study Team

(7) Study on the Necessity of Bridge Repair due to Aging

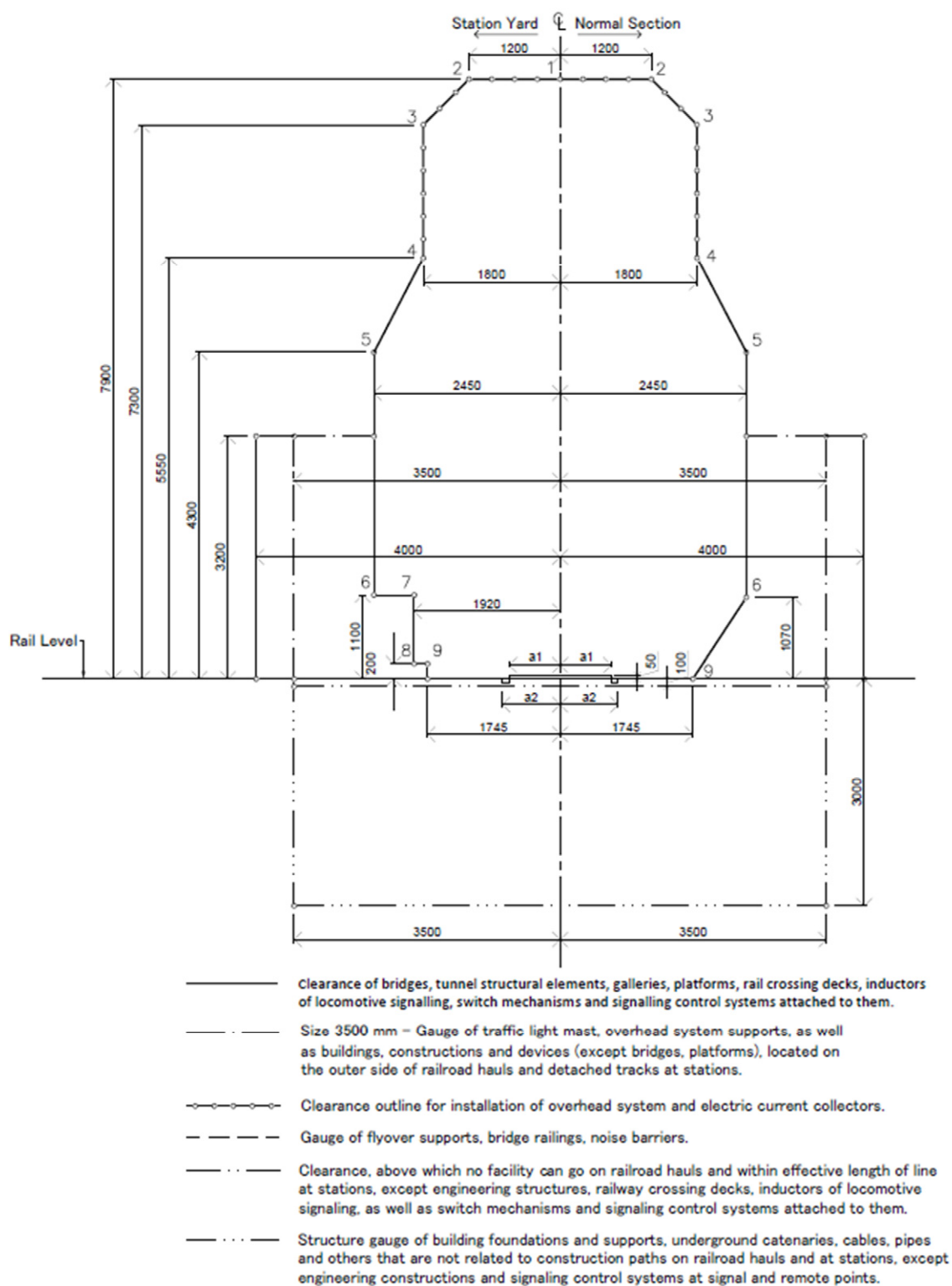
In this survey, it was not possible to confirm the condition of all the bridges in the target section, however, based on the site survey of several bridges which have been done, bridges that require immediate repair or replacement for aging was not confirmed. However, according to a hearing with ADB who is conducting an investigation of civil structures in the same section, it has been confirmed that steel bridges which need to be renovated have been identified. Therefore, it is necessary to have a detailed study regarding the soundness of all the bridges within the target section in the future supplementary survey or detailed design stage.

It is necessary to consider in detail the soundness of all bridges in the target section.

(8) Study on the Necessity of Bridge Renovation for Construction Gauge Improvement due to Electrification

In the case of railway electrification, higher construction gauge compared to non-electrification is required. Therefore, it is important to identify whether the clearance is secured on the existing

overbridges and through-truss bridges to evaluate the necessity of bridge renovation. Figure 4-24 shows the construction gauge applied for electrification considered within Turkmenistan Railway Agency.



Source: Turkmenistan Railway Agency

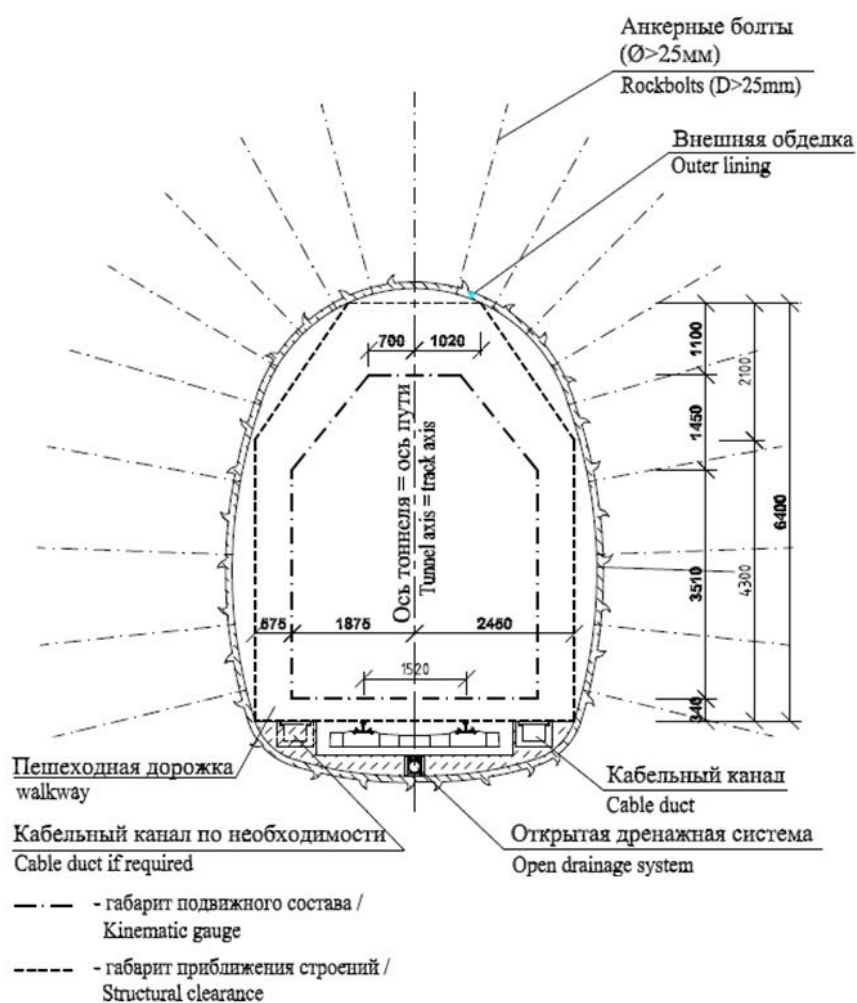
Figure 4-24 Construction Gauge for Electrification considered within Turkmenistan Railway Agency

Normally, before and after the section of railway bridges, tunnels and overbridges, the minimum construction gauge is set on the precondition of lowering the pantograph to pass the said section in order to ease the cost for construction or renovation. However, according to the construction gauge received from the Turkmenistan Railway Agency, the upper construction gauge is set as 7.9 m from the rail level without considering a minimum construction gauge.

In this survey, it was not possible to conduct the clearance investigation of all overbridges and through-truss bridges within the target section. Assuming a similar clearance as that mentioned in 3.5.3 and 3.6.4 is adopted for all bridges, it is considered that there will be a significant increase in construction cost since repair or replacement of all overbridges, pedestrian bridges and through-truss bridges will be required to meet the gauge mentioned above. Therefore, a minimum construction gauge for railway bridges, tunnels and overbridges is proposed herein.

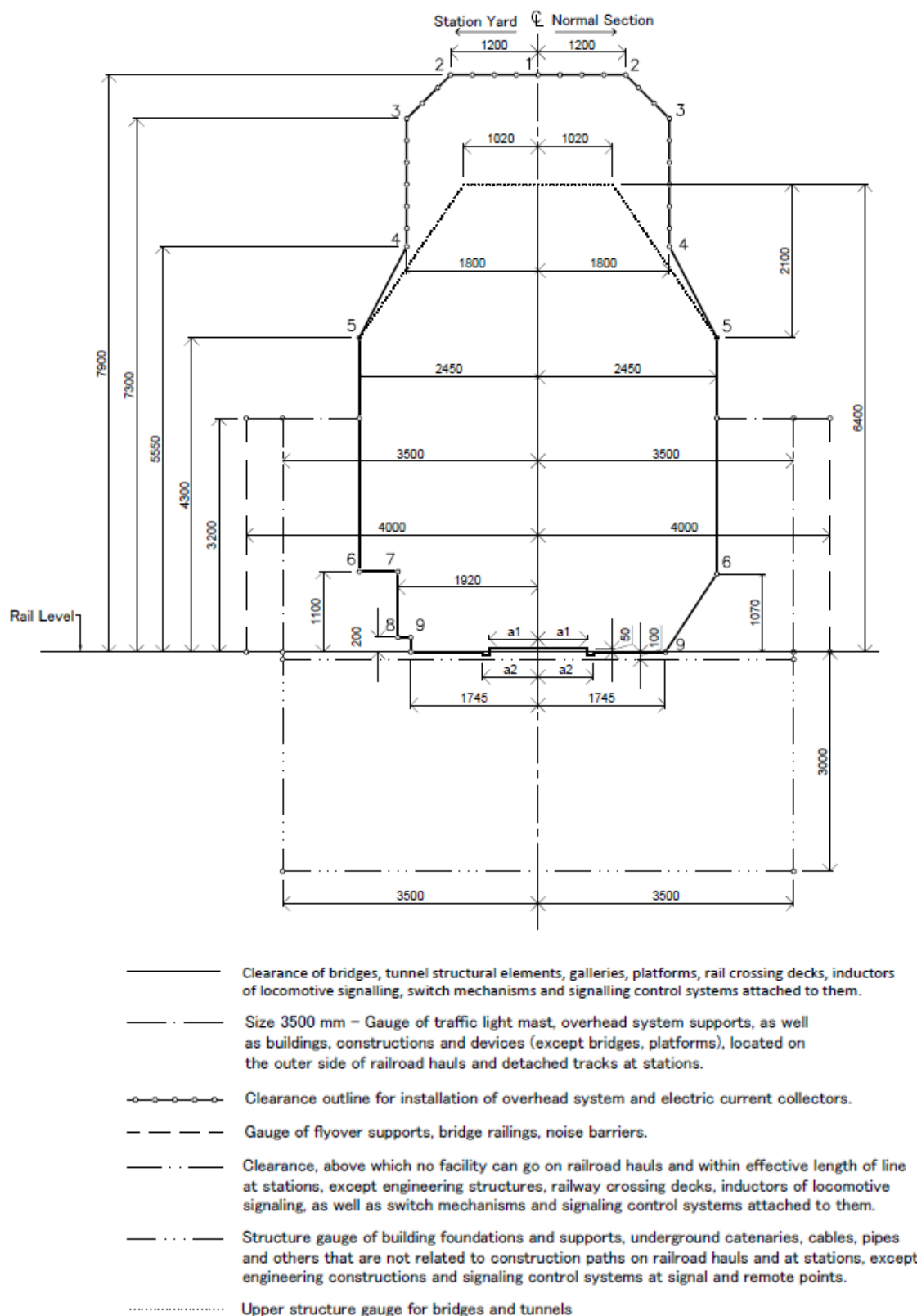
According to Former Soviet Union Railway Standard, a minimum construction gauge of 6.4 m or more is stipulated for railway bridges and tunnels. In addition, in the neighbouring country of Uzbekistan, a minimum construction gauge adopted for the tunnels between China - Kyrgyzstan – Uzbekistan which is 6.4 m, the same as the Former Soviet Union Standard (Figure 4-25). Since the width of construction gauge and the values of rolling stock gauge are the same as the values applied for electrification considered within the Turkmenistan Railway Agency, it is proposed to adopt the same minimum construction gauge as shown in Figure 4-26 .

From the above, the minimum construction gauge for railway bridges and tunnels is set as 6.4 m. Therefore, if the same clearance can be secured as the values which have been confirmed on site as mentioned in 3.5.3 and 3.5.4., it is considered that there is no need for bridge renovation. However, it is necessary to conduct clearance investigation for all overbridges and through-truss bridges within the target section in the future supplementary survey or detailed design stage.



Source: Feasibility Study of New Rail Links between the Ferghana Valley, Bishkek and Kashgar

Figure 4-25 Minimum Construction Gauge for Railway Tunnel connecting China, Kyrgyzstan and Uzbekistan



Source: Study Team

Figure 4-26 Construction Gauge for Electrification with Minimum Construction Gauge for Bridges and Tunnels (Tentative)

(9) Study on the Necessity of Level Crossing Renovation

Within the section of Gyokdepe - Bayramaly, covered by the first stage of the modernization plan, there are 53 level crossings. In Russia, the standard emergency braking distance is set as 800 m or less. Considering that the same standard is applied in Turkmenistan, as one of the Former Soviet Union Countries, a maximum speed of 160 km/h can be allowed at the plane intersection of railway and road. Therefore, for the target maximum speed of 120 km/h at the first stage of modernization plan, a plane intersection of railway and road can be allowed. However, in order to reduce level crossing accidents as much as possible, it is desirable to have a grade separated crossing such as an overpass or underpass at the intersections of railway and road. In Turkmenistan, a grade separated crossing of the road including the cost is in charged by the Road ministries and local government units, therefore, it is necessary to have advance coordination between the concerned agencies and the Turkmenistan Railway Agency and to execute the renovation of the level crossing with high priority as needed.

(10) Study on Continuous Welded Rail

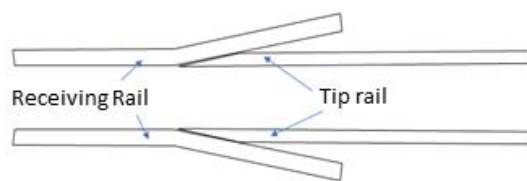
As mentioned in 3.5.2, continuous welded rail with a length of 700 m welded by a standard length rail of 25 m (or 12.5 m) was adopted in Turkmenistan. Besides, rails with length of 12.46 m, 12.44 m and 12.40 m are inserted at the expansion joint section.

For conventional lines in Japan, continuous welded rail of is adopted to 1) reduce noise and vibration, 2) improve riding comfort by lowering train swing, 3) reduce rail damage at the expansion joint section, and 4) reduce the maintenance costs of track and wheels. At both ends of a continuous welded rail, an expansion joint to cope with expansion and contraction of the rail is installed as shown in Figure 4-27 . An expansion joint is composed of “tip rail” and “receiving rail” which are specially shaped. Besides, the tip rail is tapered and is situated at the outside of the receiving rail. While the expansion and contraction occur, the mechanism enables the movement of the tip rail and receiving rail without having a gap at the joint, therefore, the wheels can pass smoothly. However, it should be noted that it is necessary to release the residual stress of the rail while installing the continuous welded rail. In addition, while the train accelerates and decelerates, rail creeping (rail slide in the longitudinal direction) would occur and cause the insufficiency or excessive of the stroke and the expansion joint may not be able to absorb the rail expansion or contraction due to temperature change. Therefore, it is necessary to control the stroke against rail creeping.

It is desirable to reduce the rail joints in order to reduce noise and vibration, improve riding comfort by lowering train swing and reduce the maintenance costs of rail and wheel; however, it may end up with accidents if the stroke control is not performed properly. Therefore, at the first stage of the modernization plan, it is proposed to adopt a continuous welded rail with a length of 700 m which is currently used in Turkmenistan. In addition, it is desirable to adopt the same expansion joint used in Japan to eliminate the gap between joints since the impact force on the rail joints would increase while the maximum speed is improved by the staged modernization plan.



Source: Wikipedia



Source: Study Team

Figure 4-27 Joint Structure for Continuous Welded Rail in Japan

(11) Study on the Countermeasures for Sandstorms

According to the hearing with the Turkmenistan Railway Agency, at the section between Ashgabat and Mary, there are some locations where the track was buried due to a sandstorm, however, the scale and range could not be specified. Therefore, it is necessary to specify the scale and range of sandstorms and to study the adequate countermeasures in the future supplementary survey or detailed design stage.

At this stage, the following three countermeasures corresponding to the scale of the sandstorm can be considered.

- Countermeasure 1 (Small Scale of Sandstorms): Install a reed barrier with a height of approximately 30 cm.
- Countermeasure 2 (Medium Scale of Sandstorms): Install a reed barrier with a height which is higher than 30 cm (Countermeasure 1).
- Countermeasure 3 (Large Scale of Sandstorms): Change railway structure to elevated type.

Countermeasure 1 is the method currently adopted for main roads in Turkmenistan to reduce the amount of scattered sand with a reed barrier of approximately 30 cm height, which is considered effective when the scale of sandstorms is small. Countermeasure 2 is the method adopted to medium scale of sandstorms which cannot be restrained by countermeasure 1. Countermeasure 3 is the method adopted to large scale of sandstorms which cannot be restrained by countermeasures 1 and 2. In the case of changing the railway structure to an elevated type, a sand path can be made underneath the railway elevated structure which is considered a possible way to reduce the maintenance work such as the discharge of accumulated sand compared to restraining sandstorms by walls.

4.4.3 Plan for Train Station Facilities

(1) Cargo Station

It is considered that it might be possible to cope with the increase in the number of trains to some extent, even with the current facilities. It depends on how trains are operated and how the station facilities are used. However, a drastic increase in the number of trains will also require a drastic increase of sidings and cargo handling equipment, as well as cargo wagons.

Taking into account capital expenditures, it is considered as realistic to start with increasing the number of locomotives and freight wagons, and then increase the transportation capacity by redesigning train operation and cargo handling methods. In the future when a detailed study will be conducted, it is desirable to consider cargo handling equipment at the cargo station.

(2) Passenger Station

As mentioned in 3.6.2, the existing passenger station is in relatively good condition, therefore rebuilding is not considered. Besides, passenger usage will be about 1.7 times of 2018 even in 2055 according to demand forecast; therefore, it is assumed to have in-vehicle ticket examination as before at the first stage of modernization plan. Regarding the platform, it is suggested to have the low platform raised up to the level of 1.1 m from the rail level to increase the convenience of getting on and off the train.

4.4.4 Plan for Electrical System

A substation system plan for electrification of the Turkmenistan Railway was prepared for proposal to the country's Railway Agency.

(1) Transmission Line Network

On examination of the transmission line network proximate to the entire Turkmenbasy-Mary-Turkmenabat railway line (with a central core of Ashgabat), core transmission lines were 220 kV, with some transmission lines of 110 kV. In addition, though 35 kV transmission towers are prevalent, consultation with State Power Corporation Turkmenenergo of the Ministry of Energy of Turkmenistan (hereinafter “Turkmenenergo”) revealed that these are unfit for railway use. As a result, suitable substation receiving voltages in this electrification plan could be 220 kV or 110 kV. However, economic and maintenance considerations suggest receiving power from 110 kV transmission lines is optimal. Despite this, 110 kV transmission networks were observed as concentrated solely in the vicinity of Mary, and transmission lines occasionally observed along the railway were only rated for low power capacity, unable to withstand the load put on by railway systems. Furthermore, since regulations prohibit branching 220 kV transmission lines between stations, the fundamental plan is to directly receive power from 220 kV substations, and to receive power intake at 110 kV substations where this is possible. Going forward,

it will be necessary to engage Turkmenenergo in detailed discussion and exploration about substation receiving voltages, transmission line capacity ratings, and where to receive electricity.

(2) Voltage Imbalance on the Power Supply Side

This plan assumes that a three-phase / single-phase conversion transformer will be used so as to reduce imbalances and voltage fluctuations in the three-phase power supply. However, the actual state of the power system equipment and/or internal matters with neighbouring countries may necessitate the consideration of changing transformers (single-phase / single-phase).

(3) Method for Protecting Transmission Lines

Final policies on protecting receiving lines and operating feeding substations should be determined in further discussion with the Railway Agency and Turkmenenergo.

(4) Power Receiving Equipment

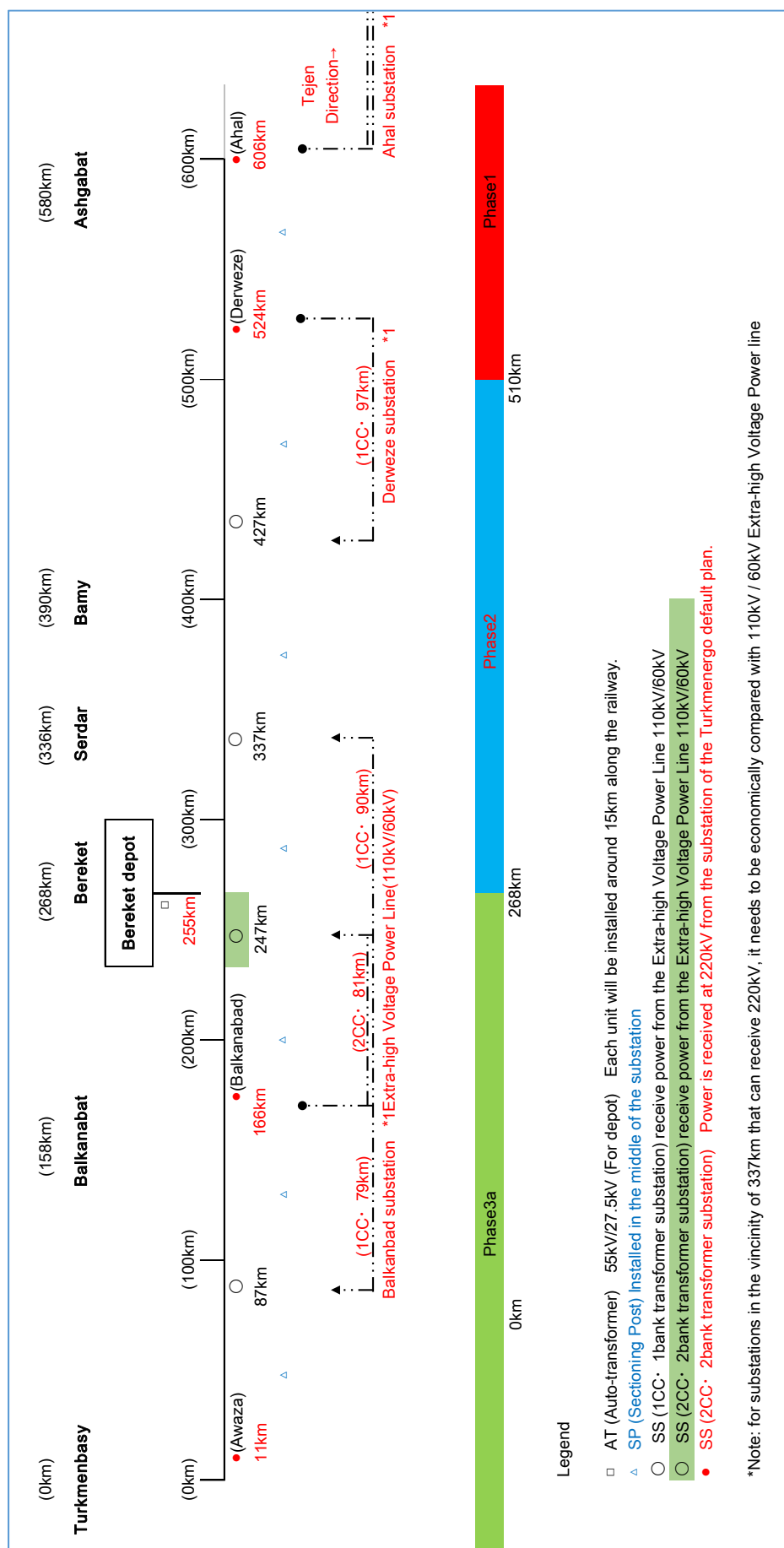
Substations were planned to receive two lines in alternation. However, according to Turkmenenergo regulations, transmission lines should in principle be directly pulled from power plants or substations, and as direct pulls are not possible for substations in all locations, plans should consider the possible eventuality of constructing a 220 kV or 110 kV connecting transmission line. As a result, this plan adopts two-line, two-bank and one-line, one-bank substations. Further, the proposal was for an equipment configuration that would not impact feeder equipment operation even in the event of an accident at a substation.

(5) Substation Plans

1) Substation Plan under the Project

(a) Substation Power Receiving plan

Figure 4-28 and Figure 4-29 show the substation locations and 110 kV (planned receiving voltage) connecting transmission line system in this plan.



The substation receiving voltage in this plan was based on Turkmenistan's domestic transmission network. Though we proceeded with a plan of 110 kV as the suitable receiving voltage for substations along the existing rail line given the state of this particular transmission network, meetings with Turkmenenergo revealed that the 110 kV transmission network system's short circuit capacity was extremely low and not enough to withstand loads generated by a railway system. Based on this, it was decided that the upper 220 kV Turkmenenergo substations, near the railway line, would provide primary receiving power, with a 110 kV connecting transmission line system under consideration. In the actual design, 220 kV and 110 kV were vastly different both monetarily and in technology, with maintenance work having commensurate gaps; this led the Railway Agency to also recognize that there was a significant difference. In addition, there are several restrictions under Turkmenenergo regulations, such as the inability to branch in the middle of a transmission line, making receiving 220 kV at all substations more economically burdensome. In addition, since there is a large 110 kV transmission network in the Mary area, substations in this area were planned to receive power directly from the 110 kV substation, with 14 substations across the entire rail line.

(b) Substation Locations

In examining substation locations, their distance intervals were determined in reference to Japan's existing conventional railway lines, with locations decided so that there would be no problems with signal equipment and electrical circuit sections near rail stations. Though we attempted to secure longer intervals between substations for the sake of economic considerations, due to the maximum feeder interval of 70 km as stipulated by the Railway Agency's regulations, more detailed discussion on power receiving systems and other issues will become necessary.

(6) Device Configuration

Feeder substations are generally outdoor configurations, but in cities, suburbs, or where safety (e.g. receiving 220 kV) merits consideration, indoor or GIS (Gas Insulated Switchgear) configurations are also to be considered. The Railway Agency is aware of GISs and is aware of the need to install automated fire suppression equipment as it pertains to fire equipment at indoor substations.

(7) Contact Line Voltage

Table 4-18 shows voltages of contact lines providing energy to electric locomotives.

Table 4-18 Train Line Voltage

Type	Voltage
Maximum voltage	27.5 kV (international standard)
Standard voltage	25 kV
Minimum voltage	17.5 - 19.0 kV, 2 minutes

Source: Study Team

* Because of non-finalized details about electric locomotives, the minimum voltage is based on information from Japan

(8) Feeding Method

Substation electric power is provided to electric locomotives via contact (overhead) lines and rails. Here, since the return side of the feeder circuit is a grounded rail, part of the return current flows to the ground. In AC-based electric railways, this outflow current (leakage current) causes inductive interference in nearby communication lines. Various feeding systems are used to suppress the outflow current. Three of the most common types of AC feeding systems are SF (simple feeding), BT (booster transformer), and AT (autotransformer). Though the simple feeding with partial BT feeding method is in use in Turkmenistan's neighbouring countries, on this occasion, we proposed the AT feed method, which is widely adopted in Japan and supports high speeds and large current, should be used.

The AT feeder system has many features that are suitable for high-speed railways, such as extending substation interval distances, significant reduction in inductive interference on communication lines, and limiting leakage current flowing from rails to the ground. For this reason, the autotransformer (AT) feeding system, which is suitable for high-density and high-power applications, is beginning to be widely adopted in Europe and other countries. Further, AT intervals are generally set at up to about 15 km. ATs are installed at each substation (SS), sectioning post (SP), and autotransformer post (ATP, or AT post). During meetings, the Railway Agency's plan also considered the AT feeding system.

(9) Feeder Circuit Configuration

1) Type and Location of Substations & Posts

In transformer substations, the discrepancy in the power supply phase between adjacent substations requires the installation of sectioning posts (SPs) between substations. The proposal was therefore for approximately 45 km of substation section distance on either side, with substation spacing of approximately 90 km. However, regulations stipulated that substation intervals must be 70 km or less. However, the fact that such provisions were issued in the absence of electrification suggests they were based on neighbouring countries' simple feeding systems. Detailed presentations and rule revisions will be required to extend these intervals. Further, autotransformer posts (ATPs, or AT posts) are provided to relieve voltage drops and reduce inductive interference of weak circuits.

2) Feeding methods per direction

A method was proposed for, when using a Scott-T transformer with 110 kV voltage, sending voltages from the secondary sides of the feeder transformer (main and teaser, abbreviated M and T) ("A" and "B" for 220 kV voltage) separately per direction to origin and terminus feeder circuits, with the substation at the centre of the system. Additionally, when using an inequilateral Scott-T transformer to eliminate single phase load imbalances, utilizing a per-direction batch feeding system was proposed.

(10) Method for Feeding System Operation

1) Phase-heterogeneous Sections

The M and T (A and B) side power of the feeder transformers are connected together directly beneath the substation and sectioning post pulls. Sectioning posts match power from different power systems. Therefore, train notch control happens before phase-heterogeneous sections so as to prevent pantograph-caused heterogeneous phase power short circuits when a train passes underneath, allowing it to pass by the section safely.

2) Extended Feed

Substations and sectioning posts are configured so as to enable the use of extended feeds. An extended feed refers to, when a failure occurs at either the A or B side at a substation, an in-phase power supply sent to an adjacent sectioning post to extend the power supply. In the event of a power outage at an adjacent substation, the sectioning post's coverage will be extended, feeding the neighbouring substation. However, feeder transformers, autotransformers, circuit breakers, and so forth are presumed to be rated as standard feeders. For places where power is received via two lines from the transmission line, two feeder transformers will be installed for regular and standby operation, with other equipment also duplicated. This makes the chance of continued power outages extremely low and results in less time restrictions on maintenance work across all line sections.

3) Feeder Circuit Voltage Drops

Feeder circuit voltage drops differ depending on certain preconditions, such as the position of the electric locomotive, the locomotive's current, the number of trains in the same feeder section, the track gradient, and the impedance of the circuit. Trial calculations will be made based on resulting maximum load conditions going forward, and this shall be set within the allowable range of fluctuation for the railway line voltage.

4) Feeder circuit Harmonics

The type of electric locomotive assumed for this proposal uses a PWM (pulse width modulation) converter to convert AC into DC power, then drives a three-phase induction motor by modulating voltage and frequency using VVVF (variable-voltage/variable-frequency) control. For this reason, the current waveform on the primary side is near to that of a sine wave. Therefore, low-order harmonic current is limited, leading to the conclusion that countermeasures against low-order harmonics are unnecessary at feeding substations. Given that high-order harmonics are suppressed by the design inside locomotive cars, they are believed to be very low-intensity.

5) Electromagnetic Induction

In the electromagnetic induction of railways, given that feeder circuit rails and communication lines correspond to the primary and secondary windings of a transformer, respectively, these constitute a rough definition of a transformer circuit, inducing voltage in communication lines due to electromagnetic induction from the rail. This voltage is proportional to frequency, leakage current, mutual inductance, and the length of the parallel section of rail and communication lines. The Turkmenistan electrification plan covers an extremely long length of 1,176 km in total, and since a large portion of this outside of urban areas is desert regions, this should be considered as specialized for urban areas. Also, when a harmonic current flows out of the vehicle load into the feeder circuit, an electromagnetically induced voltage is generated due to the harmonic. This is called line noise voltage, and the following must be considered to combat it. In order to suppress the current leaking to the ground, this proposal adopts the AT (autotransformer) method and reduces induction by actively absorbing the rail current. Shielded or optical cables should be used as communication lines, as far away from rails as possible. According to the Railway Agency, the majority of lines use optical cables, but their capacity is unknown.

(11) Feeder Transformers

In this proposal, in order to reduce the three-phase imbalance on the transmission line side, 110 kV receiving substations will normally be Scott-T transformers or inequilateral connection transformers, and 220 kV receiving substations will be modified Woodbridge-connected transformers or roof-delta connection transformers. Turkmenenergo has no experience using these types of transformers for converting from three-phase to single-phase. The benefits of using these for railway loads have been presented. In this proposal, transformers display the particular characteristics of electric railways when compared to general three-phase to single-phase conversion transformers. However, if there are national political concerns or other issues with this, a combination of three-phase transformers is also possible. For operation of transformers, the Railway Agency will install two units based on this concept, with one for ordinary use and one for standby. The two are not to be operated in parallel. If one transformer fails, feeding is switched to the standby unit to secure normal feeding circuit operation. The Railway Agency has pointed out the reliability of a one-bank, one-line configuration at substations. There is no major issue here due to support from extended feed operation. Careful explanation will be necessary in the future with regard to technical operations such as these. Further, in locations where noise is considered to be a problem, e.g. in city centres, it will be necessary to consider the state of underground substations. This may include use of low-noise transformers or use of soundproof walls around the substation.

1) Types of feeder transformers

If, like in an electric vehicle, electric power driven by a single phase (two-phase) is used from a three-phase power system, imbalance occurs on the three-phase side. This may cause various adverse effects on general equipment, and therefore it is preferable that the three-phase current be balanced as much as

possible. For this reason, substations planned by the Railway Agency will, when converting three-phase to single-phase power, use single-phase to single-phase transformers to convert the three R-S-T phases from a single transmission line. Then, at the substation, the combinations of R-S, S-T, and T-R will be alternated to reduce imbalance. However, train loads or schedule disruptions risk violating provisions stipulated by Turkmenenergo, resulting in the need to, in some instances, use expensive three-phase imbalance compensators. This was the method presented and proposed because, in Japan, feeder circuits are divided by direction so that the currents in each of the three phases are as equal as possible. Further, it was explained that in feeding systems, Scott-T transformers, inequilateral Scott-T transformers, modified Woodbridge-connected transformers, or more recently roof-delta connection transformers and other feeder transformers are used to convert three-phase power into single-phase.

2) Secondary output voltage of feeder transformers

The maximum voltage of the overhead line is 27.5 kV in the specification (assumed) of the electric locomotive. Therefore, for AT feeding systems, the secondary output voltage of the feeder transformer is 55 kV. We have proposed a transformer primary-side (no-load switching) tap that can regulate the feeder circuit's voltage so that it is at the maximum voltage in order to handle power supply voltage fluctuations.

(12) Purpose of General Distribution Lines

The Railway Agency has traditionally supplied power from stations and signaling equipment to nearby homes and housing for railway personnel performing maintenance on the same. This power is ensured, even during outages, by an emergency generator, and is also supplied to nearby general-purpose locations (e.g. homes). This custom means that even if the railway is electrified, it will be necessary to ensure power is supplied to the general public even during an emergency. This general power distribution is at a high level of 10,000 volts. Power capacity details are to be explored further going forward.

(13) Switchboards

ME (microelectronic) switchboards will be implemented on the basis that the Railway Agency has also adopted programmable controllers (PCs), digital relays, and other microcomputer-applied devices, and is seeking to miniaturize and reduce maintenance in its equipment. These switchboards will be responsible for monitoring, control, and protection. Note that when adopting ME switchboards that use microcomputer-applied devices, it will be necessary to install air conditioning equipment in the building.

(14) Remote Monitoring and Control Systems

1) Equipment overview

The power management system is based on the collective control and monitoring of the entire line from

a central command centre. However, splitting the line into a number of segments for per-segment operation and direction is possible, with additional equipment installation.

2) SCADA (Supervisory Control and Data Acquisition) system

The monitoring and control of (unmanned) feeder substations, sectioning posts, and other locations are planned to be carried out from the central command station in the city of Ashgabat. The Railway Agency has also introduced SCADA for monitoring and control of power supply equipment for signalling between the Kazakhstan border (Serhetyaka) and Bereket, and between Bereket and the Iran border (Akyayla). On the question of information transport methods between substations, other locations, and the central command station, it will be necessary in the future to explore and discuss methods with the Railway Agency in consideration of the actual, tested state of the optical cables present.

3) SCADA system features

SCADA system features include an efficient human-machine interface, consolidation of functions, improvement of visibility, and automatic control of power systems by use of information processing devices. These devices operate power systems, make determinations about incident details, and more, reducing the burden of personnel operating the control centre. Use of these devices has been proposed for these reasons.

4) Equipment Redundancy

In alternating two-line, two-bank substations, redundant backups are provided for all main equipment, including power receivers, feeder transformers, and so forth in order to ensure highly-reliable operation. However, at one-line, one-bank substations, operation over feeder circuits for the sake of economic efficiency does not inhibit system operation.

(15) Substation Installation Capacity

1) Prerequisites

The items required to calculate the transformer capacity (kVA) of a substation include the maximum current of the electric locomotive (A), the sum of the maximum body weight and cargo tensile load of the electric locomotive (t), the feeding distance (km), the number of trains (number per hour), the locomotive power factor (pf), and the power consumption rate (kWh per thousand ton-kilometres). However, detailed figures for these have not been determined as yet, and final substation capacity will be calculated after this is resolved.

2) Locomotive-Related Data

Substation design targets stable train operation based on assumed data on electric locomotives and train schedules. (Show conditions required to calculate substation capacity)

(16) Contact Line Equipment

On-site studies or technical meetings with the Railway Agency with regard to contact line equipment have not been conducted. These were determined from observation of the geography in different areas of the existing lines. A comprehensive study will be necessary to inform execution.

1) Supports

Considering that deserts constitute a large portion of Turkmenistan, there are only a number of tunnel sections or underpasses, with the vast majority being open track. Since there is a non-electrified single track in operation already, poles will be constructed to serve as supports along the railway track.

Depending on the location, either concrete or steel poles will be used, with construction to take into consideration seismic resistance pending future meetings. In addition, a hinged cantilever system for the line support, which enables high-speed travel, is proposed.

2) Contact line method

In the interest of trolley wire wear, speed characteristics, and economics, it is proposed that contact lines use either a heavy simple catenary system with single contact wire, or a CS (copper-steel) simple catenary system with single contact wire. Further, an appropriate insulator will be selected based on research into pollution distributions in each region, matching its respective pollution classification. One insulator type option is the polymer insulator, which has seen increasing use in Japan recently. Overhead ground wires (GWs) are installed in locations where lightning damage is to be expected, grounded (max 30 ohms) every 200 meters, and insulated with suspension insulators to differentiate between lightning and fault current.

3) Pole Building and Hinged Cantilever Installation

At present, there are no roads for construction use along the non-electrified sections that are in operation, and there are only three hours of work time considering the train schedule. This presents a severe situation for construction work. Though utility pole installation is possible by machine if construction workers can utilize general roads to get near their planned locations, we believe that hinged cantilevers will generally need to be installed manually.

4) Erection of Contact Lines

In contact line erection, the proposal is that all catenary and trolley wires are to be constructed by machine using overhead line installation or work vehicles. However, the amount of work that can actually be done in two hours is about one drum's worth (appr. 1,200 to 1,600 meters). The only work that can be done with a road-rail vehicle loaded with a drum is on the trolley wire, messenger, and hanger. The GW, AF (at feeder), NW (neutral wire), and fastenings require separate methods. In addition, the road-rail vehicle must be removed from the main line within the three-hour work period; considerations on this vehicle's movements, interception devices, and so forth remain issues for future resolution. In the future, it will be necessary to carry out a detailed study in consideration of how to carry out construction work under such conditions. In addition, it is believed that it will be a point of contention as to how many parties the line construction will be allotted to.

(17) Stage One Electrical System Plan

Planning will establish substations for each section of the Geokdepe-Ashgabat-Mary-Bayramaly portion of the line. The track length between Geokdepe and Bayramaly is approximately 452 km. In this section, there will be 6 substations, 5 sectioning posts, and one transformer post every 14 km to 15 km. Each substation will be installed up to around 90 km apart, and sectioning posts will be set up almost halfway between each substation pair. Though the standard receiving voltage is 220 kV, it is planned to receive 110 kV at substations planned near Mary due to the prevalence of 110 kV transmission lines in this area. In addition, though substations with a receiving voltage of 220 kV will receive power from Turkmenenergo transmission lines, Turkmenenergo provisions prohibit drawing mid-line by use of T or π branching. All pulls are to be from substations or power plant premises. There are only two feeder substations close to Turkmenenergo power plants. The remaining four either require endless transmission lines pulled from Turkmenenergo power stations or substations, or installation of connecting transmission lines by the Railway Agency. On this occasion, it was not possible to conduct all necessary field surveys or have detailed meetings on the subject, but in case there are substations or switchyards between power plants, branching could be possible. In the event that connecting transmission lines become necessary, it appears that the Railway Agency would consider 220 kV transmission lines necessary for stable power supply. However, the Agency recognizes in comparisons to the 110 kV connecting transmission lines proposed by the Japanese side that there are significant differences both in the technical and monetary senses. In addition, in the event that connecting transmission line systems are put into use, it appears that maintenance would be outsourced to Turkmenenergo, and there is some intent to transfer the equipment outright in the future. The first phase of the modernization plan mainly includes Ashgabat, the capital of Turkmenistan. Construction of substations in such a carefully crafted city, with no transmission lines or utility poles, presents a fair amount of difficulty. Even if installed in a somewhat distant location, they may need to be underground substations or GIS (gas insulated switchgear) indoor substations. The Railway Agency is also aware of GISs and has explored the installation of automatic fire suppression

equipment for any underground substations. Remote monitoring and control systems are to be managed at a control centre in the capital of Ashgabat, where equipment status is monitored, incident alerts are provided, and equipment is controlled for the applicable substations and sectioning posts.

4.4.5 Plan for Signal and Telecommunication

(1) Signal

The number of running trains will increase due to the improvement of speed by track improvement and train renewal. It is necessary to review the track circuit length according to the maximum operating speed and train transportation density on the improved route. Accordingly, signal equipment needs to be added or renewed. (Signals, train detections, train protection equipment, etc.) Also, as for interlocking devices, the age of equipment at each station (each halt) and the degree of aging are expected to be different, therefore it is necessary to make an improvement plan with consideration of the status of equipment at each station and the importance of the operation plan. When introducing the technology of a Japanese company, it is necessary to refer to the control of existing interlocking devices (route control, release, etc.) and make specifications that do not hinder existing equipment and maintenance.

Regarding the operation management system, it is necessary to confirm the upper limit such as the number of controllable trains in the specifications of the existing system and determine whether the system can withstand the increase in the number of operations or double track. Even if the existing system can be used, it is necessary to compare and review the cost of upgrading the existing system and the cost of renewing it, and determine the policy in consideration of the impact of the facility improvement work on commercial operation.

The composition is divided and distributed in each assigned area, and taking into account the possibility of increased freight traffic and the possibility of increasing the number of high-speed trains, it is necessary to take some measures to increase the train density in the future with regard to information sharing between sections.

(2) Telecommunication

In determining the specifications of the optical cable, it is necessary to select a sufficient number of cable cores and devices in consideration of an increase in the future network configuration and communication volume. Regarding the addition or renewal of communication equipment, the determination of the system and the plan of system configuration should be done in consideration of the configuration and usage of the existing system and technical trends. Since all substations need to be managed when electrification is performed, the amount of communication for information collection and remote control would increase. In addition, since the number of running vehicles would be surely increased, the traffic between the train and the ground facilities (stations and control centres) would increase (calls, future monitoring functions,

etc.). Further, the communication volume between the station and the control centre is likely to increase in the future by adding surveillance cameras and providing service information, so it is necessary to have sufficient expandability and margin. In the case that double-tracking section plan is performed, safety measures must be considered against obstacles to the opposite track. The train protection function including the necessity of adopting the function will be examined. Monitoring of various weather conditions (wind, earthquake, rainfall, etc.) for safe operation needs to be studied together with economic efficiency.

If the section where the communication line is converted to an optical cable will be electrified in the future, it is considered that the influence on the communication guidance failure is small internally. However, in the places where the electrified section approaches existing general communication lines, it is necessary to take countermeasures against communication guidance failures, therefore, prior coordination with related organizations is required.

(3) Issues to be noted in the Future

When a new Japanese-made vehicle is introduced, it must be verified that it can function sufficiently with the existing train detection system. In addition, when the speed is improved by using an existing device, it is necessary to confirm whether the performance of various devices can be sufficiently exhibited with the increase in the speed.

It is necessary to establish an interface with existing systems for the lines and boundaries of each phase that are not covered by this project so that the existing systems are not affected. Introduce devices for the interface as needed.

When Japanese companies enter, it is important to provide information on the weather conditions (temperature, daytime temperature difference, humidity, wind power, sandstorm) in Turkmenistan, especially for equipment installed outdoors or in vehicles. For example, when introducing a general automatic train stop system (ATS) in Japan, it is necessary to investigate whether the specifications in Japan can be applied.

Regarding construction, the plan needs to be developed with many factors and adjustments including whether the maintenance plan for equipment and systems can be performed with existing equipment, when to update it, whether the civil engineering construction plan is consistent, and the impact on commercial operation. In addition, confirm the consistency with other plans of the Turkmenistan government is required as well.

In order to improve the accuracy of the project cost, it is necessary to summarize the required specifications in consultation with Turkmenistan and define the required performance for each device. In particular, for signals and communication systems, a safety-conscious design is required. For this reason, it is necessary to conduct more detailed site inspections and grasp the status of existing facilities.

4.4.6 Plan for Rolling Stocks

One of the important points in planning for rolling stocks is the maximum speed. The current operating speed is up to about 70km/h, whereas the future target speed is 100km/h for cargo trains and 120km/h for passenger trains. From the field survey, the following points are summarized as points to be noted for speeding up.

(1) Securing adequate braking force

1) Reviewing load-compensating device

The current braking device of vehicles has a load-compensating device to adjust the braking force depending on loading status. As shown in Table 4-19, it generates three levels of braking force.

Table 4-19 load-compensating device of vehicles

Position	Loading status
Full	Heavy load
Half	Light load
Zero	No load

Source: Study Team

These three levels of braking force is however considered too rough in that it cannot cope with more various levels of loading status, therefore not enabling more adequate braking force. Moreover, a load-compensating device needs to be set manually when loading. Hence, it is recommended that the load-compensating device be automated by weighing real-time loading status, generating an adequate braking force. This can be made possible by automatically detecting a deflection amount of bogie caused by loads, turning it into air pressure which generates adequate braking force.

2) Shortening of Idle Running Time

The current air braking device (Figure 4-30) generates a time lag when controlling the brake valve, by a transmission of pressure change in the brake pipe. This means that there is a time lag between applying the brake and when actually it stops, which is called “idle running time”. This idle running time needs to be shortened for increasing the maximum speed or increasing the service frequency.



Source: Study Team

Figure 4-30 Current Air Braking Device

To improve this, an electromagnetic valve can be used together with the brake valve to minimize the time lag caused by the transmission of pressure change in the brake pipe. This should shorten “idle running time” of the brakes for each unit of vehicle, improving the brake synchronization.

(2) Wheel Structure for Diesel Locomotive

The wheels of the current diesel locomotives seem “tired wheel type”. While it has an advantage that only tires need to be replaced when the tires are worn out, there is a disadvantage that it can be expanded and lose by the thermal expansion when braking. Therefore, an introduction of “mono block wheel” should be considered for the safety operation in line with increasing the speed.

(3) Specifications of Locomotives

In consideration of the above issues, the introduction of electric locomotives and wagons compatible with high speed is proposed. For passenger trains, the introduction of EMU is proposed. The assumed specifications of the electric locomotive and EMU are shown in Table 4-20 and Table 4-21.

Table 4-20 Considered Electric Locomotive Specifications

Item	Specification
Electric Method	Standard overhead line voltage: AC 25 kV @ 50Hz, minimum voltage: AC 19 kV
Train Composition	Electric locomotive, double-headed
Train weight	4,200 tons
Train power output	Max. 6,000 kW x 2 (heads) = 12,000 kW
Single-unit output	6,000 kW (with variable output: 4,000 kW or 3,000 kW)
Maximum Operating Speed	120km/h
Wheel Type	Tire / centre wheel system

Source: Study Team

Table 4-21 Considered EMU Specifications

Item	Specification
Electric method	Standard overhead line voltage: AC 25 kV @ 50Hz, minimum voltage: AC 19 kV
Composition	5 Cars (3M2T)
Capacity	5 Cars, total 315 passengers
Body Structure	Double Coated Aluminium Structure (Airtight)
Maximum Operating Speed	200km/h

Source: Study Team

Table 4-22 shows the number of rolling stocks required for the first stage modernization. The required number of electric locomotives is described as of section 4.4.1 and the EMUs are calculated by the ratio of day trains to night trains based on passenger demand. The cargo wagons will be compatible with an electromagnetic automatic air brake system in order to reduce the idle running time. The required number of cargo wagons is calculated based on the number of cargo wagons by age obtained from the RA. .

Table 4-22 Number of Rolling Stocks Required for First-stage Modernization

Type of Rolling Stocks	Required Nos.
Electric Locomotive	45 Nos.
EMU	6 Sets (total 30 nos)
Cargo Wagon	4,200 Nos.

Source: Study Team

4.4.7 Plan for Depots and Workshops

Regarding the plan for the depots and workshops, the precondition is set as the number of cargo wagons will be about the same as the current number of wagons even after the electrification.

(1) Features of Diesel and Electric Locomotives

The features of diesel and electric locomotives are shown in Table 4-23.

Table 4-23 Structural Features of Diesel and Electric Locomotives (only Important Parts)

Device	Diesel locomotive	Electric Locomotive
Power supply method	Engine or Generator	Overhead catenary lines
Engine	○	×
Generator	○	×
Pantograph	×	○
Transformer	○	×
Electronic components	×	○
Motor	×	○

Source: Study Team

As shown in Table 4-23, when using an electric locomotive, maintenance of large equipment such as engines and generators is not required. Therefore, there is a possibility that the present workplace can be

effectively utilized by modifying the layout.

On the other hand, there are some new equipment that is not required for diesel locomotives, such as pantographs, transformers, electronic equipment parts and AC motors etc.

In general, if the amount of maintenance work required of a diesel locomotive is compared to an electric locomotive, the amount of work is less in the case of the electric locomotive.

(2) Consideration for Electric Locomotives

The existing workshops carrying out diesel locomotive inspections are considered to be able to perform electric locomotive inspections by adding some capital investment and modifying the layout. However, it is necessary to consider whether overhead catenary lines can be installed or not in the future. In addition, the pre-condition is that the cargos are almost the same as it is at present.

There have been several points identified during the field visit for the existing workshop to be renovated for Electric Locomotive inspection as follows.

1) Installation of Overhead Catenary Lines and Circuit Breakers and Inspection

After the installation of the entire electric locomotive line, in order to perform an inspection as the final check, it is necessary to work on the electrified line and it is necessary to lay an overhead power supply line.

When laying overhead lines, it is necessary to erect poles to support the overhead catenary lines, and it is necessary to confirm that these can be installed in the existing space between tracks. Figure 4-31 shows an example of the overhead catenary line.



Source: Study Team

Figure 4-31 Overhead Catenary Line

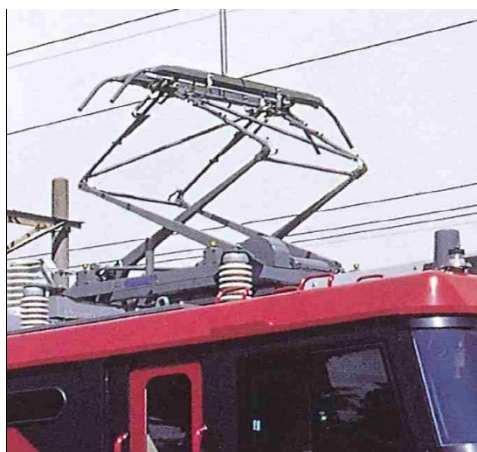
In addition, when inspecting the equipment on the roof of the electric locomotive, it is necessary to cut off the power of the overhead line, therefore, it is necessary to install a circuit breaker that can turn the power of the overhead line on and off whenever necessary.

At the field survey, overhead cranes are observed in the workplace that can be used for the electric locomotive inspection. However, the present overhead cranes may hinder with the overhead catenary lines, thus, some kind of modification is required.

Incidentally, two lines in the inspection and repair room in Bereket Depot is recommended as a candidate location to carry out inspection (pattern 1 to 3) conditional to the work area needs to be improved. One of the four lines in Ashgabat locomotive workshop is considered as a candidate place to be used as a repair workshop.

2) Inspection Area for Pantograph

Basically, a pantograph used for collecting electricity from overhead catenary lines at the time of overhaul. Since there is a possibility that an accident might occur during the operation of the electric locomotive, it should be considered to set up an inspection and testing facility at Ashgabat Workshop. Figure 4-32 shows the image of a pantograph.



Source: Study Team

Figure 4-32 Pantograph

(3) Testing Machines for AC Motor

Despite the fact that it is easier to do an inspection on an AC motor than for a DC motor leading to a smaller workshop for AC motors, a rotation test with no-load still needs to be carried out, therefore, workspace and the machines for testing are required.

1) Testing Machine for Air-Brake Valve

It is most likely that an air-brake valve used for electric locomotive is different from the conventional air-brake valve, thus the working method and testing procedure can be different. Therefore, a testing machine for the new air-brake valve is required, whereas, the current facilities can be used for dismantling and assembling. It means the current layout needs to be reviewed as the existing testing machine will be no longer in use.

2) Flaw Detection Procedure of Bogie Frame

It is considered that increasing speed will increase the probability of a bogie frame developing a flaw due to the amplified vibration of the bogie or its frame. Such a flaw should be repaired at an early stage so that it does not get worse. “Magnetic particle inspection equipment”, which has a higher precision in detecting flaws, will be introduced in this matter.

3) Other

In addition to clearing up facilities and equipment those are no longer in use in the depot and workshop, the entire layout also needs to be redesigned, such as, preparation of a storage space for the equipment to be repaired. In this regard, it is desirable to separate the workspace and spare-parts storage space between the diesel locomotive and electric locomotive as much as possible. All the spare parts should be labelled such as, “code”, “name”, and “shape”. In addition, carefulness is also required to pick up the spare parts for diesel locomotive and electric locomotives.

4.4.8 Project Cost Estimation

Same as the preconditions described in 4.3.3(5).

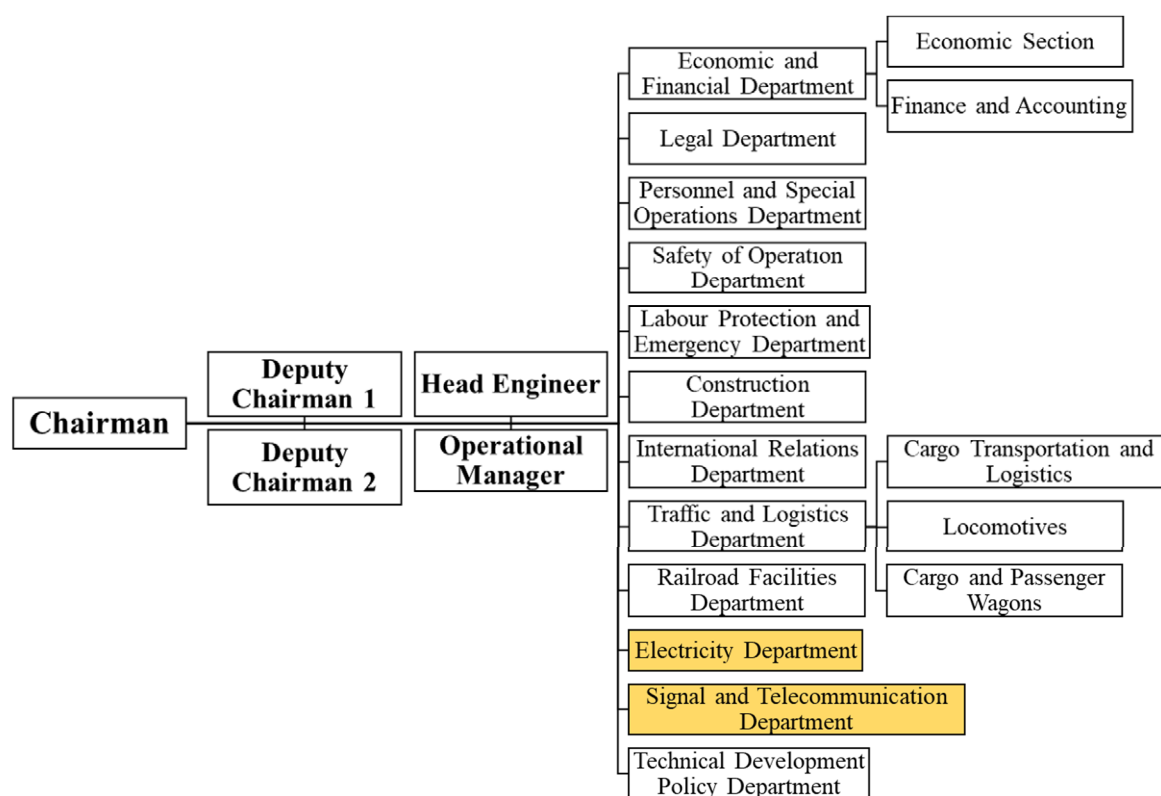
Table 4-24 Estimated Project Cost of the First Stage

Item		Amount	Percentage (%)
Electricity	Substation	130.1	13
	Transmission Lines	113.3	
	Electric Power Command Centre	11.1	
	OHC	95.2	
Telecommunication		423.1	15.8
Renovation of Depot (inclusive of E&M)		154	5.8
Rolling Stocks	Electric Locomotive	290.5	23
	Passenger Train (EMU)	132.8	
	Freight Train	193.7	
Signalling	Signal, ATP, Cable, etc.	366.4	17.5
	Interlocking (Main Station)	58.1	
	Interlocking (Normal Station)	35	
	ATS at Ashgabat	9.2	
Civil Works	Maintenance and Repair against Mud-Pumping	45.3	24.9
	Procurement of MTT	18.9	
	Replacement of Damaged Rail	77.3	
	Replacement of Rail Bond for Electrification	0.1	
	Replacement of Rail Fastening System and Sleeper	153.4	
	Installation of Entry Prevention Fence	99.6	
	Installation of Temporary Road for Construction	36.3	
	Double-Tracking Works (inclusive of bridge, embankment and rail)	230.5	
	Level Raise-up of Platform	4.1	
Subtotal		2,678.00	100
Contingency (5%)		133.9	—
Engineering Cost		118.1	—
Total		2,930	—

Source: Study Team

4.4.9 Management Plan

As the operation and maintenance of railways is still being carried out properly by the Railway Agency, so it is expected that they will continue to operate and maintain the railway even after modernization. However, in order to improve electrification and signal & telecommunication systems, and to maintain and manage them properly, it is desirable to establish a new department dedicated to power, signal & telecommunication. As for the other departments, the department in charge of cargo and the department in charge of tracks need to maintain and manage much more carefully than present due to speed up. Therefore, increasing the number of personnel and strengthening the maintenance capacity will be an obvious need.



Source: Study Team

Figure 4-33 Proposed Management Organization Chart

4.4.10 Economic and Financial Analysis

In order to evaluate the financial and economic performance of the first stage of the modernization plan, economic and financial analyses were conducted for the section Geokdepe – Ashgabat – Mary – Bayramaly.

(1) Economic Analysis

1) Overview

The purpose of economic evaluation is to verify the effects of the project and to evaluate the economic viability of the project. In the economic evaluation, a positive effect on the national economy considered as a benefit and the consumption of resources held by the national economy considered as a cost are used in order to evaluate whether the project contributes to the national economy.

The economic evaluation is based on the cost-benefit analysis that compares economic benefits and costs with cash flow.

2) Basic Prerequisites

The basic prerequisites for economic analysis are as follows.

- Evaluation period: 36 years (30 years after the start of operation), assuming the residual value is zero.
- Year of operation: 2027
- Social discount rate: 10%.
- Inflation rate is not considered
- Exchange rate : 1USD = 3.5 TMT

3) Economic Benefits

“With Project” is the case when the project is implemented, and, “Without Project” is the case when the project is not implemented. The economic benefit is defined as the difference in costs between the cases of “With Project” and “Without Project” such as fuel cost and time cost.

The expected benefits of implementing the project are considered as travel time savings (TTS) and fuel cost savings for cargo and passengers. Indicators such as ton-kilometres, ton-hours, and man-hours related to traffic volume are used based on the travel demand forecast results.

(a) Benefits from Travel Time Savings of Cargo

Cargo hourly cost was calculated by adding up hourly cargo opportunity cost, hourly employee opportunity cost and hourly vehicle opportunity cost.

The hourly opportunity cost of a cargo was calculated using the export prices and export volume (in tonnes) based on the Statistical Yearbook of Turkmenistan (2018) and other sources for 14 type of products and by multiplying the value of a cargo by the long-term interest rate (16%). Here, Uzbekistan's interest rate was used for the long-term interest rate, because information on Turkmenistan was not available.

In the ‘With Project’ case, increased freight demand can be transported by the railway, but in ‘Without Project’ case, the railway transportation volume capacity is limited as the number of trains are limited, so there is a possibility that the exceeded freight volume will be transported by trucks. For this reason, it is assumed that for the case if 120% of the freight traffic volume in 2018 (20% increase of 2018), an additional amount will be transported by truck in the target section. The hourly opportunity cost of the employees of the transport companies and hourly opportunity cost per vehicle is calculated accordingly.

The hourly opportunity cost for the employees of the transport companies were calculated by dividing the gross national income per capita (USD 6,740, as per the World Bank) in 2018 by 219 working days per year and 7.5 hours working per day. Hourly opportunity cost per vehicle was calculated based on the new purchase cost per truck as 50,000 USD, depreciation period as 10 years and residual value as 1,000

USD. In addition, the operating days of one year were calculated as 90% of the year, and the operating hours per working day were calculated as 10 hours.

(b) Benefits from Travel Time Savings of Passengers

To calculate travel time savings for passengers, the difference of travel time cost before and after the modernization work is calculated. The travel time cost of ‘Without Project’ case is calculated based on the current scheduled speed (46 km/h) and the number of passengers of the target section and in the case of ‘With Project’ it is calculated based on the improved scheduled speed (90 km/h for passenger trains; 80km/h for cargo trains). The time value was calculated by dividing the gross national income per capita (USD 6,740 as per World Bank) in 2018 by 219 working days per year and 7.5 hours of working hours per day.

(c) Benefits from Fuel Cost Savings

Same as before, in order to calculate the fuel cost savings it is assumed that if the cargo volume will increase as 120% of 2018 (increased by 20% of 2018), an additional amount will be transported by diesel driven trucks for the target section. Therefore, the benefits are calculated as the extra consumption which could be saved. The diesel price for private transports in Turkmenistan is 1,617 TMT/ton as of January 2020, including VAT. Excluding VAT from this amount, the unit cost is converted to about 0.33 USD/litre. However, since the government subsidies included in the diesel price is not clear, the benefits are calculated assuming that diesel price of 0.55 USD/litre with reference to the diesel price in neighbouring Uzbekistan, Kazakhstan and Afghanistan.

(d) Result of Economic Benefits

The results of economic benefits for the year of 2027, 2040 and 2055 of the project is shown in Table 4-25.

Table 4-25 Economic Benefits

Year	Economic Benefits (million USD)			
	Freight Time Savings	Passenger Time Savings	Fuel Cost Savings	Total Benefits
2027 (Operation start)	23	74	23	119
2040	99	88	101	288
2055	247	109	252	608

Source: Study Team

4) Economic cost (project cost, operation and maintenance cost)

The project cost and operation and maintenance (O&M) cost of this project are as follows. The O&M cost is set as 1% of the project cost. The ratio of economic price to market price is set at 0.85. In addition to the initial investment, it is assumed that locomotives will be purchased every five years as the demand increases.

Table 4-26 Economic Cost

Project Cost (economic price)	2,491 Million USD
Additional Rolling Stocks Investment (economic price)	674 Million USD
Maintenance Cost (economic prices)	775 Million USD

Source: Study Team

5) Cost Benefit Analysis

Cost-benefit analysis is conducted based on the economic cost and benefits which are estimated above and the analysis results are shown in Table 4-27. The economic internal rate of return is 6.7%, which is lower than 10-12%, generally used as a standard for cost-effectiveness for public works investment. However, as this time the benefits are difficult to calculate due to data constraints and other factors such as the benefits which are difficult to convert into money. By considering these effects, it can be said that this is a cost-effective public project. Benefits which could not be calculated this time include reducing greenhouse gas emissions, benefits due to increase of future time value, reducing traffic accidents and the ripple effects of economic development.

Table 4-27 Cost Benefit Analysis Results

Index	Result
Economic Internal Rate of Return (EIRR)	6.7%
B/C Ratio *	0.64
Net Present Value (NPV,USD million)*	-698

Note: Social Discount Rate 10%

Source: Study Team

(2) Financial Analysis

1) Overview

The purpose of the financial analysis is to verify the financial relevance of the project from the perspective of the project implementing entity. This evaluation is performed based on the estimated revenues, construction cost and operation and maintenance cost. A cash flow analysis is done on the assumption that the investment will not be affected by the funding conditions excluding interest cost.

2) Basic Prerequisite

The basic prerequisites for financial analysis are as follows.

- Evaluation period: 36 years (30 years after the start of operation), assuming the residual value is zero.
- Year of operation: 2027
- The executing agency will be Railway Agency of Turkmenistan.
- Uzbekistan's long-term interest rate index of 16% was adopted, because the long-term interest rate in Turkmenistan have not been published
- Inflation rate is not considered
- Exchange rate : 1USD = 3.5 TMT

3) Revenue Calculation

The revenue of this project is set as cargo and passenger usage fees. Based on the sales of the Department of Finance of Railway Agency in 2018, the following per-conditions are set and calculated accordingly.

- The revenue collection from the cargo business is proportional to the cargo demand based on the demand forecast result
- The revenue collection from the passenger business is proportional to the passenger demand based on the demand forecast result
- Other business revenue is proportional to the sum of the sales of cargo and passenger businesses
- Revenue of 2055 is calculated based on the growth rate of demand forecasts up to 2055.

Table 4-28 Income from Revenue Income

Year	Revenue Income (million USD)			
	Cargo	Passenger	Others	Total
2018	267	29	169	464
2027	442	34	272	748
2055	987	49	593	1,628

Source: Study Team

4) Cost (Project cost and O&M cost)

The project cost and operation and maintenance cost of this project are described in Table 4-29. The initial investment is based on the cost estimation results of the first stage modernization plan. It is assumed that O&M cost will increase as import cost will increase, based on the RA's 2018 income

statement. In addition, 1% of the initial investment was added as the O&M cost of the new infrastructure in the target section.

Table 4-29 Cost

Initial Investment (financial price, USD million)	2,930
Additional Investment (financial price, USD million)	2,336
O&M Cost (financial price, USD million)	36,687

Source: Study Team

5) Cash Flow Analysis

A cash flow analysis is done based on the costs and revenues calculated in the above sections. The analysis results are shown in Table 4-30. The financial internal rate of return (FIRR) is calculated as -4.8%, indicating that it is difficult to repay the initial investment from the RA's own revenue alone, even if the increase in demand is expected in the future.

Table 4-30 Result of Cash Flow Analysis

Index	Result
Financial Rate of Return (FIRR)	- 4.8%
Net Present Value (NPV, USD million)	-1,413

Source: Study Team

6) Sensitivity Analysis

Because it is difficult for the RA to independently operate the project under the current tariff system, a sensitivity analysis was performed for cases where the Turkmenistan government will provide certain subsidies and when revenue will increase. Table 4-31 sets four different cases and calculates the financial internal rate of return (FIRR), when the government pays for some items. As a result, in Case 4, even if the government decides to pay for substation, transmission line, electric power command centre, depot renovation, and civil works, the FIRR is still negative.

Table 4-31 Sensitivity Analysis of FIRR (changes due to government subsidies)

Case	Substation	Transmission Line	Electric Power Command Centre	OHC	Locomotive	Depot Renovation (Including E&M)	Signaling	Telecommunication	Civil Works	FIRR	Government Subsidies [million USD]
1	RA	RA	RA	RA	RA	RA	RA	RA	RA	-4.8%	0
2	RA	RA	RA	RA	RA	RA	RA	RA	G	-3.2%	727
3	RA	G	RA	RA	RA	G	RA	RA	G	-2.3%	1,019
4	G	G	G	RA	RA	G	RA	RA	G	-1.8%	1,173

Note: RA= Railway Agency; G = Subsidy from Turkmenistan Government. 'G'は政府による補助金。

Source: Study Team

Table 4-32 shows the cases where the revenue structure is revised and the cargo fare is increased by 20%. It is assumed that the cargo demand does not change from the base case and the passenger revenue is the same as in the base case. In this case, the FIRR has been improved, with 5.3% for Case 1 and 11.7% for Case 4. This shows that financial sustainability can be improved by reviewing the cargo fare structure in addition to government subsidies.

Table 4-32 Sensitivity Analysis of FIRR (changes due to government subsidies and the effect of 20% increase in freight revenues)

Case	Substation	Transmission Line	Electric Power Command Center	OHC	Locomotive	Depot Renovation (Including E&M)	Signaling	Telecommunication	Civil Works	FIRR	Government Subsidies [million USD]
1	RA	RA	RA	RA	RA	RA	RA	RA	RA	5.3%	0
2	RA	RA	RA	RA	RA	RA	RA	RA	G	8.3%	727
3	RA	G	RA	RA	RA	G	RA	RA	G	10.3%	1,019
4	G	G	G	RA	RA	G	RA	RA	G	11.7%	1,173

Source: Study Team

5. Evaluation of Environmental and Social Impacts

5.1 Current Situation of Environmental and Social Aspects

5.1.1 Natural Environment

(1) Geography, Hydrology, Topography and Geology

Turkmenistan is located in Central Asia and is covered by Karakum Desert whose area occupies 85% of the national land. Most of the land is covered by plains, but the south is bordered by the Kopet Dag Mountains, the west is by the Caspian Sea, and the northwest is by the Amu Darya River.



Source: topographic-map.com

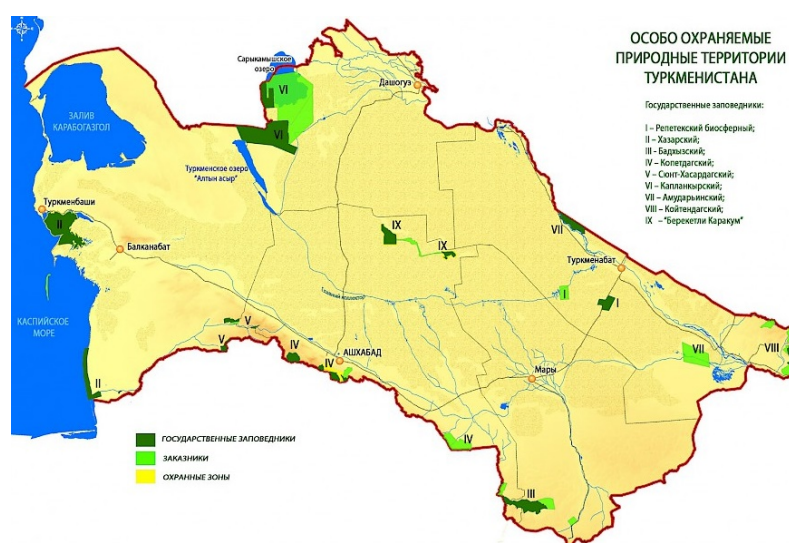
Figure 5-1 Geology of Turkmenistan

(2) Fauna and Flora

There is the Red Book data list for fauna and flora in Turkmenistan. For the reason, these species are compared with the results of environmental surveys in the project and Environmental Management Plan (EMP) and Environmental Monitoring Plan (EMoP) should be prepared if listed endangered species are existed along the project site.

(3) Conservation Area

According to the Ministry of Agriculture and Environmental Protection (MoAEP), nine protected areas are designated in Turkmenistan as shown below.



Source: Protected Natural Areas of Turkmenistan, MoAEP

Figure 5-2 Map of Conservation Areas in Turkmenistan

Table 5-1 List of Conservation Areas in Turkmenistan

No.	Name	Area (km ²)	Type of area
I	Repetek Biosphere State Reserve	346	State Reserve, Sanctuary
II	Hazar State Nature Reserve	2,690	State Reserve
III	Badkhyz State Nature Reserve	877	State Reserve, Sanctuary
IV	Köpetdag Nature Reserve	497	State Reserve, Sanctuary, Security Zone
V	Sünt-Hasardag Nature Reserve	303	State Reserve, Sanctuary
VI	Gapsangyr Nature Reserve	2,822	State Reserve, Sanctuary
VII	Amudarya State Nature Reserve	495	State Reserve, Sanctuary
VIII	Köýtendag Nature Reserve	271	State Reserve, Sanctuary
IX	Bereketli Garagum Nature Reserve	870	State Reserve, Sanctuary

Source: Protected Natural Areas of Turkmenistan, MoAEP

5.1.2 Social Environment

(1) Population

According to the Statistical Yearbook of Turkmenistan 2018, the population ratio in urban and rural areas is more than half in rural areas except for the Balkan Region, indicating that the population distribution is sparse. As for the gender ratio, the female ratio is high than the male one except in the Ahal Region, and the female ratio accounts for more than half of the national average compared with the male one.

Table 5-2 Population composition ratio in Turkmenistan

City/ Region	Ratio in urban and rural areas		Ratio in male and female	
	Urban	Rural	Male	Female
Ashgabat City	100.0	0.0	49.6	50.4
Ahal Region	36.1	63.9	50.0	50.0
Balkan Region	81.5	18.5	49.8	50.2
Daşoguz Region	30.3	69.7	49.8	50.2
Lebap Region	45.2	54.8	49.9	50.1
Mary Region	27.2	72.8	49.9	50.1
Whole Country	47.1	52.9	49.9	50.1

Source: Statistical Yearbook of Turkmenistan 2018, State committee of Statistics of Turkmenistan

(2) Land Use

As a result of an on-site survey between Ashgabat and Turkmenabat, it is considered that large-scale land acquisition and involuntary resettlement will not occur in the urban and suburban areas along the railway because the area is supposed to be secured for railway widening.



Vicinity of Ashgabat station



Section between Ashgabat and Mary



Section between Mary and Turkmenabat



Vicinity of Turkmenabat

Source: Study Team

Figure 5-3 Land Use along the Railway Section of Target Route

5.2 Environmental Improvement Effects of Project Implementation

(1) Air quality and Noise

Electrification for railways makes air quality and noise levels, along railway lines, improve. The quality and level throughout the country will also be improved by the reduction of road traffic by proceeding with the modal shift from truck transport to rail transport.

(2) Local economy such as employment and livelihood, etc.

The livelihood of residents will be improved by promoting employment as construction workers for the project.

(3) Land use and utilization of local resources

Local economy is also enhanced by the promotion of the distribution throughout increasing the number of trains.

(4) Existing social infrastructure and services

The quality of existing social infrastructure and services will be improved by electrification for railways and increasing the number of trains.

(5) Accident

The frequency of accidents will be decreased by the reduction of road traffic with proceeding with the modal shift from truck transport to rail transport.

(6) Greenhouse effect gas

As the fuel for railway will be converted from light oil to electricity by the electrification of railways, the amount of greenhouse gas emission reduced by the difference as below.

$$= (Lg - Eg) \times D$$

Lg: the unit for greenhouse gas emission for light oil

Eg: the unit for greenhouse gas emission for electricity

D: Haul Distance converted from trucks to electrified railway

5.3 Environmental and Social Impacts of Project Implementation

Environmental and social impacts for railway electrification projects is considered. In the following scoping matrix, items that are expected to be affected or are unknown at the moment are checked. In

addition, the evaluation, when the impact is hardly expected, is left blank, and details of each evaluation are described below each table.

Table 5-3 Scoping Matrix

	No.	Impact Activities Impacted Item	Comprehensive evaluation	Pre-construction/under					Comprehensive evaluation	Operation			
				Land acquisition and loss of inventory	Cutting and filling soil and digging with land modification	Operation of construction heavy machine and dump trucks	Installation of high-voltage line and wire-pole and construction of	Construction Waste		In flow of construction participant And establishment of base camp	Electrification for railway	Increasing of number of trains	Reduction of freight transportation vehicle
Pollution	1	Air pollution	✓			✓							
	2	Water pollution	✓		✓		✓						
	3	Waste	✓					✓	✓				
	4	Soil contamination	✓		✓								
	5	Noise and vibration	✓			✓			✓		✓		
	6	Land subsidence											
	7	Offensive odour	✓						✓				
	8	Bottom sediment											
Natural environment	9	Conservation area	✓		✓	✓	✓	✓					
	10	Ecosystem	✓		✓	✓	✓	✓	✓		✓		✓
	11	Hydrology	✓		✓								
	12	Topography and Geology	✓		✓								
Social environment	13	Land acquisition and involuntary resettlement	✓	✓									
	14	Poor classes	✓	✓									
	15	Indigenous and ethnic people	✓	✓									
	16	Local economy such as employment and livelihood, etc.	✓	✓									
	17	Land use and utilization of local resources	✓		✓								
	18	Water use and its rights	✓		✓								
	19	Existing social infrastructure and services	✓		✓								
	20	Social institutions such as social infrastructure and local decision making institutions											
	21	Maldistribution of benefit and damage											
	22	Local conflict of interest	✓						✓				
	23	Cultural heritage	✓		✓								

	No.	Impact Activities Impacted Item	Comprehensive evaluation	Pre-construction/under						Comprehensive evaluation	Operation			
				Land acquisition and loss of inventory	Cutting and filling soil and digging with land modification	Operation of construction heavy machine and dump trucks	Installation of high-voltage line and wire-pole and construction of	Construction Waste	In flow of construction participant And establishment of base camp		Electrification for railway	Increasing of number of trains	Reduction of freight transportation vehicle	Existence of high-voltage line and related facilities
	24	Landscape	✓				✓			✓				✓
	25	Gender	✓						✓					
	26	Children's rights												
	27	Health (Infectious diseases such as HIV/AIDS, etc.)	✓						✓					
	28	Labour environment including labor safety	✓				✓							
Others	29	Accidents	✓			✓	✓			✓		✓		
	30	Cross border impact and climate change												

※✓: Survey required or unknown item at the moment, Blank: No need survey

Source: Study Team

Table 5-4 Scoping result

Category	No.	Item	Evaluation for scoping		Reason for evaluation	
			Pre-CP CP	OP		
Pollution	1	Air pollution	✓		CP	Temporal negative impacts are caused by construction machines and dump trucks.
					OP	Operation activities which have negative impact to air pollution are not scheduled in this project.
	2	Water pollution	✓		CP	Water pollution is estimated by digging at the section crossing the river.
					OP	Operation activities which have negative impact to water pollution are not scheduled in this project.
	3	Waste	✓		CP	Construction waste such as sand and gravel is estimated. And there is a possibility of discharged organic wastewater in case of that base camp is installed.
					OP	Operation activities related to waste generation are not scheduled in this project.
	4	Soil contamination	✓		CP	There is a possibility of soil contamination if construction waste is left for a long period.
					OP	Oil contamination will occur by oil leaks at refuelling time if petroleum storage tanks will be installed at candidate land for freight depot.
	5	Noise and	✓	✓	CP	Negative impacts are caused by construction machines and dump trucks.

Category	No.	Item	Evaluation for scoping		Reason for evaluation	
			Pre-CP CP	OP		
		vibration			OP	There is a possibility that increased number of trains can make level of noise and vibration rise along the railway.
	6	Land subsidence			CP	Construction activities which leads to subsidence are not scheduled in this project.
					OP	Operation activities which leads to subsidence are not scheduled in this project.
	7	Offensive odour	✓		CP	There is a possibility of offensive odour in case a base camp is installed.
					OP	Operation activities related to offensive odours are not scheduled in this project.
	8	Bottom sediment			CP/OP	The activities which have negative impact to bottom sediment are not scheduled in this project.
Natural Environment	9	Conservation area	✓		CP	Temporal negative impact will occur because of land modification and operation of construction heavy machines at the section passing through a conservation area.
					OP	Operation activities which have negative impact to conservation area are not scheduled in this project.
	10	Ecosystem	✓	✓	CP	Negative impact for ecosystems will be offered by cutting and filling soil, operation of construction heavy machines and construction waste.
					OP	Ecological habitats may be disrupted by the presence of high-voltage lines and related structures.
	11	Hydrology	✓		CP	Negative impact for hydrology will be offered by cutting and filling soil.
					OP	Operation activities which have negative impact to hydrology are not scheduled in this project.
	12	Topography and geology	✓		CP	Negative impact for topography and geology will be offered by cutting and filling soil.
					OP	Operation activities which have negative impact to topography and geology are not scheduled in this project.
Social Environment	13	Land acquisition and involuntary resettlement	✓		Pre-CP	It is necessary to investigate the possibility of land acquisition and involuntary resettlement during detailed design.
					CP/OP	The activities which have negative impact to land acquisition and involuntary resettlement are not scheduled in this project.
	14	Poor classes	✓		Pre-CP	It is necessary to investigate the possibility of people with poor classes during detailed design.
					CP/OP	The activities which have negative impact to people with poor classes are rarely scheduled in this project.
	15	Indigenous and ethnic people	✓		Pre-CP	It is necessary to investigate the possibility of Indigenous and ethnic people during detailed design.
					CP/OP	The activities which have a negative impact to Indigenous and ethnic people are rarely scheduled in this project.
	16	Local economy such as employment and livelihood, etc.	✓		Pre-CP	The livelihoods may be affected if resettlement occurs.
					CP/OP	The activities which have negative impact to local economy are rarely scheduled in this project.
	17	Land use and utilization of	✓		Pre-CP	Negative impact for land use and utilization of local resources will be offered by cutting and filling soil.

Category	No.	Item	Evaluation for scoping		Reason for evaluation	
			Pre-CP CP	OP		
		local resources			CP/OP	The activities which have negative impact to Land use and utilization of local resources are not almost scheduled in this project.
	18	Water use and its rights	✓		CP	Negative impact for water quality for drinking and agriculture will be offered by cutting and filling soil.
					OP	The activities which have negative impact to water use and its rights are rarely scheduled in this project.
	19	Existing social infrastructure and services	✓		CP	Negative impact for existing social infrastructure and services will be offered by cutting and filling soil.
					OP	The activities which have negative impact to existing social infrastructure and services are rarely scheduled in this project.
	20	Social institutions such as social infrastructure and local decision making institutions			CP/OP	The activities which have negative impact to social institutions are rarely scheduled in this project.
	21	Maldistribution of benefit and damage			CP/OP	The activities which have negative impact to maldistribution of benefit and damage are rarely scheduled in this project.
	22	Local conflict of interest	✓		CP	The conflicts will occur if local people are dissatisfied with the employment and income of construction workers coming from outside, and the workers do not respect local community, culture and tradition, and do not treat all of them with respect.
					OP	The activities which have negative impact to local conflict of interest are rarely scheduled in this project.
	23	Cultural heritage	✓		CP/OP	It is necessary to investigate the presence of cultural heritage along the railway during detailed design.
Social Environment	24	Landscape	✓	✓	CP/OP	It is expected that the landscape will be affected by installation of high-voltage line and wire-pole, and construction of related facilities and its existence.
	25	Gender	✓		CP	In construction work, male workers are dominant due to hard work, which may not be a comfortable environment for female workers.
					OP	The activities which have negative impact to gender are rarely scheduled in this project.
	26	Children's rights			CP/OP	The activities which have negative impact to children's rights are rarely scheduled in this project.
	27	Health (Infectious diseases such as HIV/AIDS, etc.)	✓		CP	Infectious diseases such as HIV/AIDS, etc. may be spread by inflow of construction workers.
					OP	The activities which have negative impact to infectious disease are rarely scheduled in this project.
	28	Labour environment including labour safety	✓		CP	It is necessary to improve labour environment for construction workers in accordance with related laws and regulations in Turkmenistan.
					OP	The activities which have negative impact to labour environment are rarely scheduled in this project.

Category	No.	Item	Evaluation for scoping		Reason for evaluation	
			Pre-CP CP	OP		
Others	29	Accidents	✓	✓	CP	As construction vehicles pass along existing roads or side roads of the railway, minor collisions with nearby residents or livestock may increase. In addition, when electrification for railway is implemented while keeping the current train schedule, collision accidents between the train and construction vehicles may occur.
					OP	It is expected that the possibility of accidents with nearby residents and livestock will increase due to the increase in the number of trains.
	30	Cross border impact and climate change			CP	The activities which have negative impact to cross border and climate change are not scheduled in this project because deforestation is not expected and the number of construction heavy machine is limited. .
					OP	The activities which have negative impact to cross border and climate change are rarely scheduled in this project

※✓: Survey required or unknown item at the moment, Blank: No need to survey

Pre-CP: Pre-construction Phase, CP: Construction Phase, OP: Operation Phase

Source: Study Team

5.4 Summary of Laws and Regulations Related to Environmental and Social Considerations in the Host Country

5.4.1 Summary of Laws and Regulations Related to Environmental and Social Considerations

The laws regulation, and guidelines for environmental impact assessment in Turkmenistan are covered in various sectors. The outline is shown in the below table.

Table 5-5 Main Environmental and Social Laws and Regulations in Turkmenistan

Category	Law, regulation and guideline
Constitution	• Constitution of Turkmenistan, 1992 (Section 10 th in the 1 st Chapter)
General Environment	• Environmental Audit Law, 2019
Environmental Impact Assessment	• Environmental Impact Assessment Law, 1995 • National Standard of Turkmenistan for Environmental Impact Assessment on the proposed economic and other activities, 2001
Air pollution	• Air protection Law, 1996 • Protection Law for Ozone Layer, 2009 • Radiation Safety Law, 2009
Water pollution	• Hydrometeorological Activities Law, 1999 • Water Code, 2004 • Sanitary Code, 2009 • Drinking Water Law, 2010
Forest management and biodiversity	• Plant Law, 1993 • Animal Wildlife Law, 1997 • Hunting Management Law, 1998 • Biodiversity Strategy and Action Plan for Turkmenistan, 2002 • Forest Code, 2011 • Conservation Law for Fishery and Aquatic Biological Resources, 2011
Climate change	• National Climate Change Strategy of Turkmenistan, 2012
Other natural resources management	• Specially Protected Natural Territories, 1992 • Nature Conservation Law, 2014
Other Environmental conservation and consideration	• Hydrocarbon resources Law, 2008 • Protection Law of national intangible cultural heritage, 2015 • Waste Law, 2015 • Chemical Safety Law, 2011
Land acquisition and resettlement	• Property Law, 1993

Source: Study Team

5.4.2 National Standard of Turkmenistan for Environmental Impact Assessment on the proposed economic and other activities (2001)

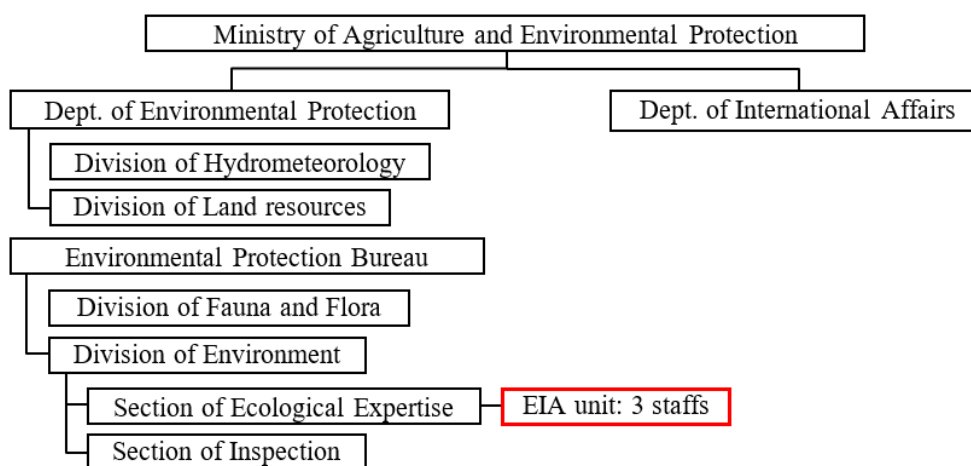
The EIA National Standard for Environmental Impact Assessment (EIA) was issued on June 2001 and stipulates the criteria required for EIA and its procedure. Under the National Standard, the Ministry of Agriculture and Environmental Protection (MoAEP) specifies the EIA procedure as a mandatory item for project implementation from an environmental point of view and submits the EIA results to the National Environmental Council. Environmentally hazardous activities are defined in the table below, and a new railway installation project over 700 km are also classified in this category. The project proponent submits a project proposal for screening process to MoAEP, and MoAEP judges the project's category as to whether a project is required with EIA process or not. The evaluation period for application documents by MoAEP is stipulated within one month from the date of the application, but if MoAEP evaluates that the contents of the documents are incomplete, MoAEP will instruct the project proponent to reapply it.

After the application documents are received by MoAEP, the project proponent will execute a survey by requesting a specialized environmental company registered with MoAEP according to the proposed scoping list, and will compile the survey result into the EIA report. Environmental Management Plan and Environmental Monitoring Plan should be included in the report, and the minutes of public consultation and the list of participants should be also attached. In the case of railway project, an outline report on the environmental and social conditions for the entire railway line should be prepared as a primary EIA report. Subsequently a secondary EIA report should include detailed specific regional information with attachment of the certificate issued by each regional government that the land acquisition and resettlement issues have been resolved. The review period of the report by MoAEP is specified as 3 months for the EIA project and 1 month for other projects. However, if MoAEP judges that the contents of the report are incomplete, MoAEP will request a re-application to the project proponent, or MoAEP can establish the Environmental Council by their own and request to an Independent Specialized Agency to conduct an environmental investigation. The investigation results are compiled into an environmental review report and are used as the final decision for EIA. However, the project proponent cannot commence their project until the positive conclusion and approval issued by MoAEP for the environmental review report. The organization chart of MoAEP is also shown as below.

Table 5-6 List of Environmentally Hazardous types of Economic and Other Activities

Contents of activity
1. Types of economic activity
Chemical, petrochemical and oil refining industries
Industry of building materials (glass, cement, asbestos products and others)
Biochemical, biotechnological, pharmaceutical production
Production, transportation and processing of oil and natural gas
Processing, transportation, storage and burial of hazardous waste
Production, transportation, storage and use of mineral fertilizers, pesticides and pesticides
Storage and transportation of combustible, explosive, toxic substances, including materials that form toxic products of combustion, including:
- Metallurgical production;
- Pulp and paper production;
- CHP plants and other installations for burning fuel with a thermal capacity of 300 megawatts or more.
2. Types of other activities
Trading ports, as well as inland waterways and ports for inland navigation
Large dams and reservoirs. Construction of motorways, express roads, tracks for long-distance railway transport (over 700 km) and runways with a length of 2100 m or more
All types of activities in the Caspian Sea and coastal zone

Source: Environmental impact assessment planned economic and other activities in Turkmenistan, National Standard of Turkmenistan



Source: MoAEP

Figure 5-4 Organization Chart of MoAEP

5.4.3 Land Acquisition

The project proponent who is likely to execute the land acquisition needs to explain the outline of the project to the Division of Land resources in MoAEP. Afterwards, discussion involving government offices, local residents, etc., in each region and city having jurisdiction over the project area is held respectively. The approval from the Cabinet of Minister of Turkmenistan needs to be obtained as a final step.

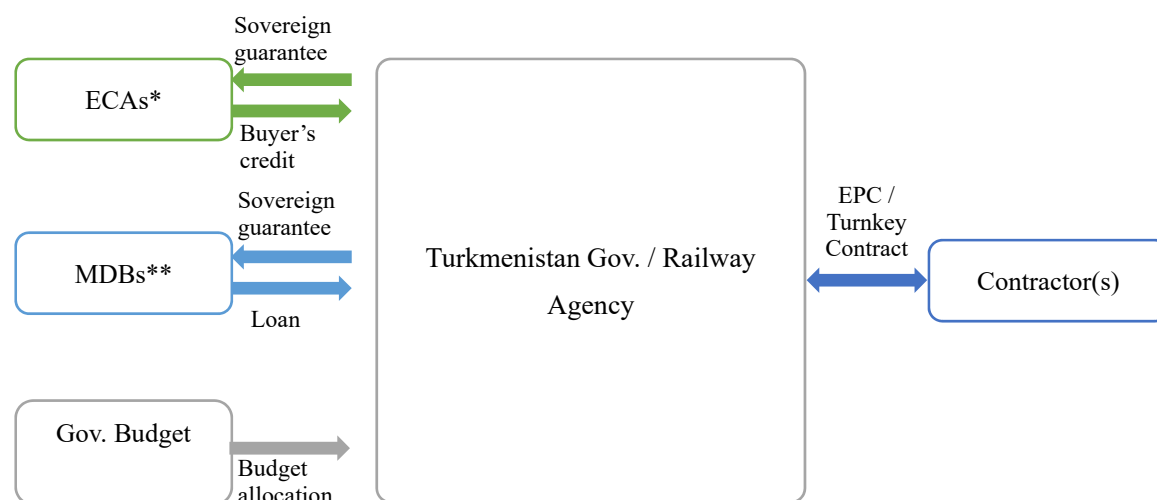
5.5 Necessary Actions by the Host Country for Project Implementation

The EIA procedures and land acquisition (if any) in Turkmenistan require not only for the central government but also for the provincial government and for local governments. It is necessary to disclose information widely and to work to strengthen the cooperation by each government from the early stage. In addition, the installation method of transmission lines connected from a power plant and the construction of the receiving substation for electrification for the railway are likely to be designated as the inseparable projects, therefore, it is necessary to carefully study the routes and the installation methods.

6. Outlook for Operation Plan and Project Financing

6.1 Implementation Scheme

The implementation scheme of this project is expected to be either Engineering, Procurement and Construction (EPC) contract or turnkey contract. The necessary funds are expected to be received from the Export Credit Agencies (ECA), the International Development Banks (MDB) and the government budget of Turkmenistan, etc. It is quite natural that in order to utilize the funds from the ECAs and the MDBs, a government guarantee (Sovereign Guarantee) is required. The executing agency is preferably the Turkmenistan Railway Agency. However, in the case of government guarantee or implementation of a subsidized project by the Turkmenistan government, it is expected that the Turkmenistan government will be the implementing entity. Figure 6-1 shows the expected project implementation scheme.



*ECA : Export Credit Agency

**MDB : Multilateral Development Bank

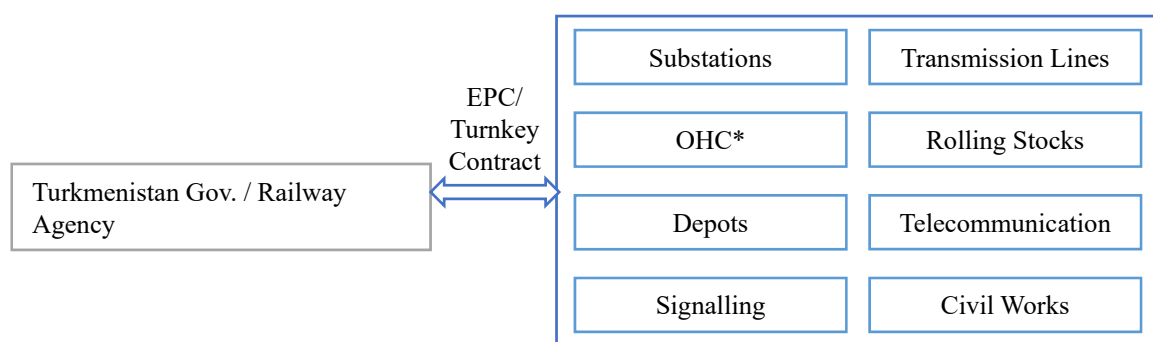
Source: Study Team

Figure 6-1 Project Implementation Scheme

6.2 Possible Contract Packages

Three cases of possible contract packages are shown in Figure 6-2 (case 1), Figure 6-2 (case 2) and Figure 6-4 (case 3).

In case 1, all components are combined into one package assuming a turnkey contract will be in effect. It is suitable when the technical ability and contract management ability of the implementing entity are limited. This type of package is easy to supervise as an implementing entity, however, if the contract size becomes large, it is difficult to separate funds when multiple ECAs and MDBs are involved. In addition, when the contractors are in large in scale, the number of companies could implement the project is limited.

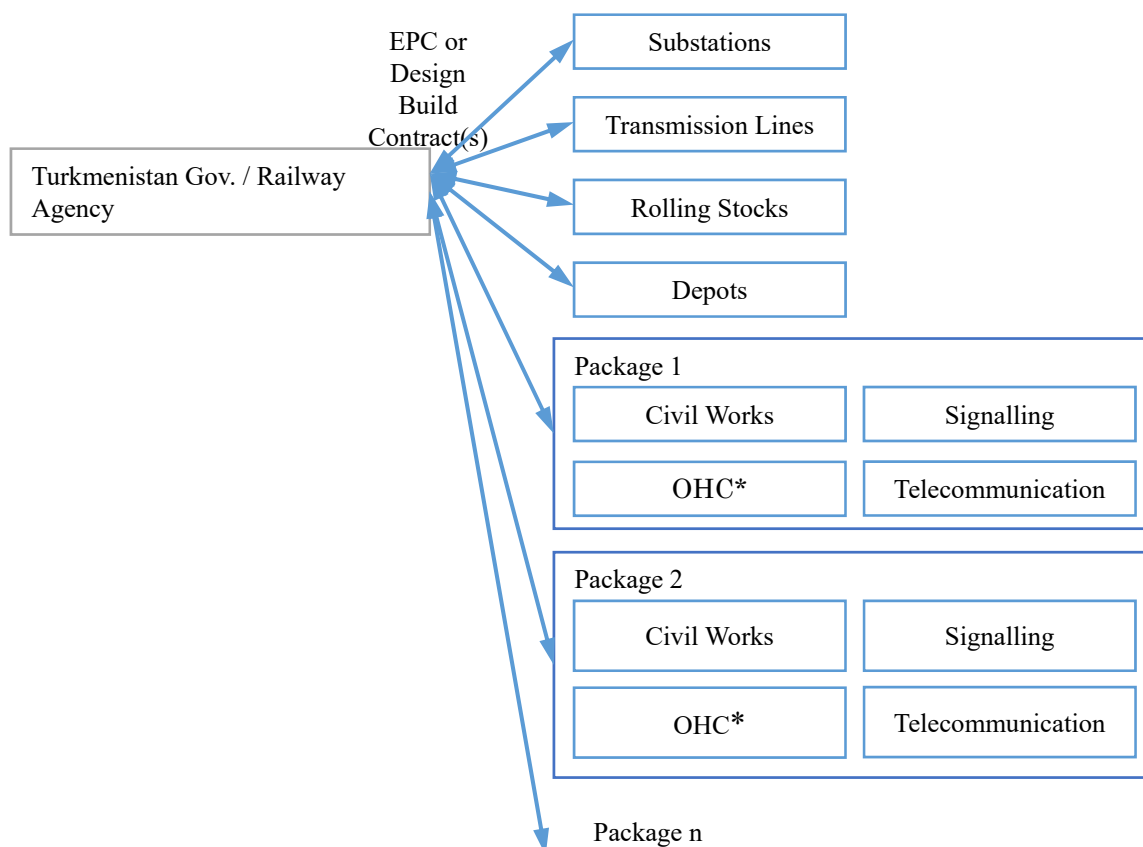


*OHC : Overhead Catenary Line

Source: Study Team

Figure 6-2 Example of Contract Package (Case 1)

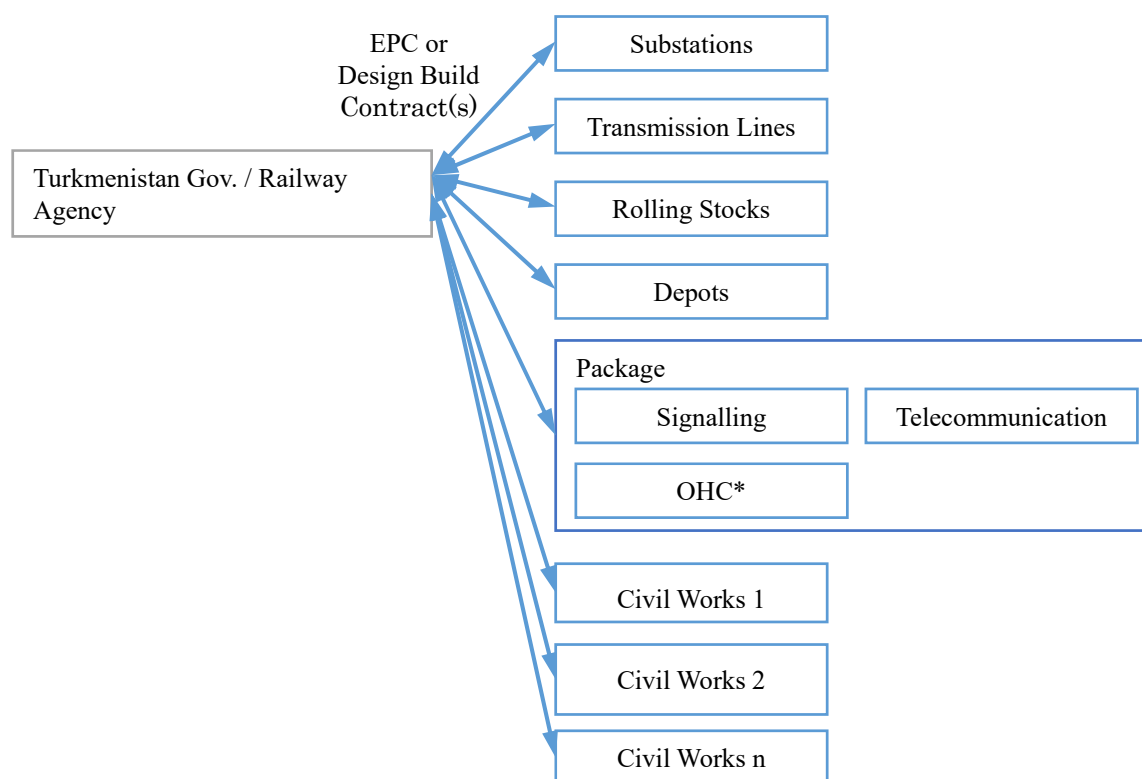
In Case 2, an EPC (Engineering, Procurement and Construction) or design build contract need to be signed for each major component. In the case of civil works, signalling, telecommunication, and OHC, they need to be coordinated with each other, so it is desirable to combine them in a single package. On the other hand, if these four components are combined for the entire section, the scale of the project will be quite large. Therefore, it is divided into multiple packages. It is necessary to decide how to divide the packages for the entire section by considering the number and size of candidate contractors in a detailed study in the future.



*OHC : Overhead Catenary Line
Source: Study Team

Figure 6-3 Example of Contract Package (Case 2)

In case 3, signalling, telecommunication and OHC is considered under single package, whether civil works has been divided into several packages.



*OHC : Overhead Catenary Line
Source: Study Team

Figure 6-4 Example of Contract Package (Case 3)

Among these which case is desirable for this project needs to be proposed, after considering the required project budget, the number of companies, the implementation capacity of those companies, etc., which are assumed to be carried out in a detailed study in the next stage.

7. Project Implementation Schedule

Figure 7-1 shows the project implementation schedule for the first stage modernization described earlier. In the future, it is necessary to collect information for the loan appraisal and examine the feasibility of the project through conducting a feasibility study (F/S). The steps up to conducting F/S and tender assistance is referred to as the “F/S and tender assistance stage,” which might require about 16 months. After that, in the case of the EPC (Engineering, Procurement and Construction) contract, the procurement procedure of the EPC contractor requires about one year in the “procurement stage”. EPC contract design, procurement, and construction will take about three and a half to four years at the "EPC contract stage," followed by a defect liability period. In order to shorten the construction period, here some stages are proposed as done in parallel before the previous stage is completed. Procurement of the rolling stocks and wagons is an item that is likely to be a critical path on the project implementation schedule. When conducting a full-scale F/S in the future, it is necessary to consider the availability of production lines of the manufactures and the time required to respond to the GOST standard, which is Russia's technical standard.

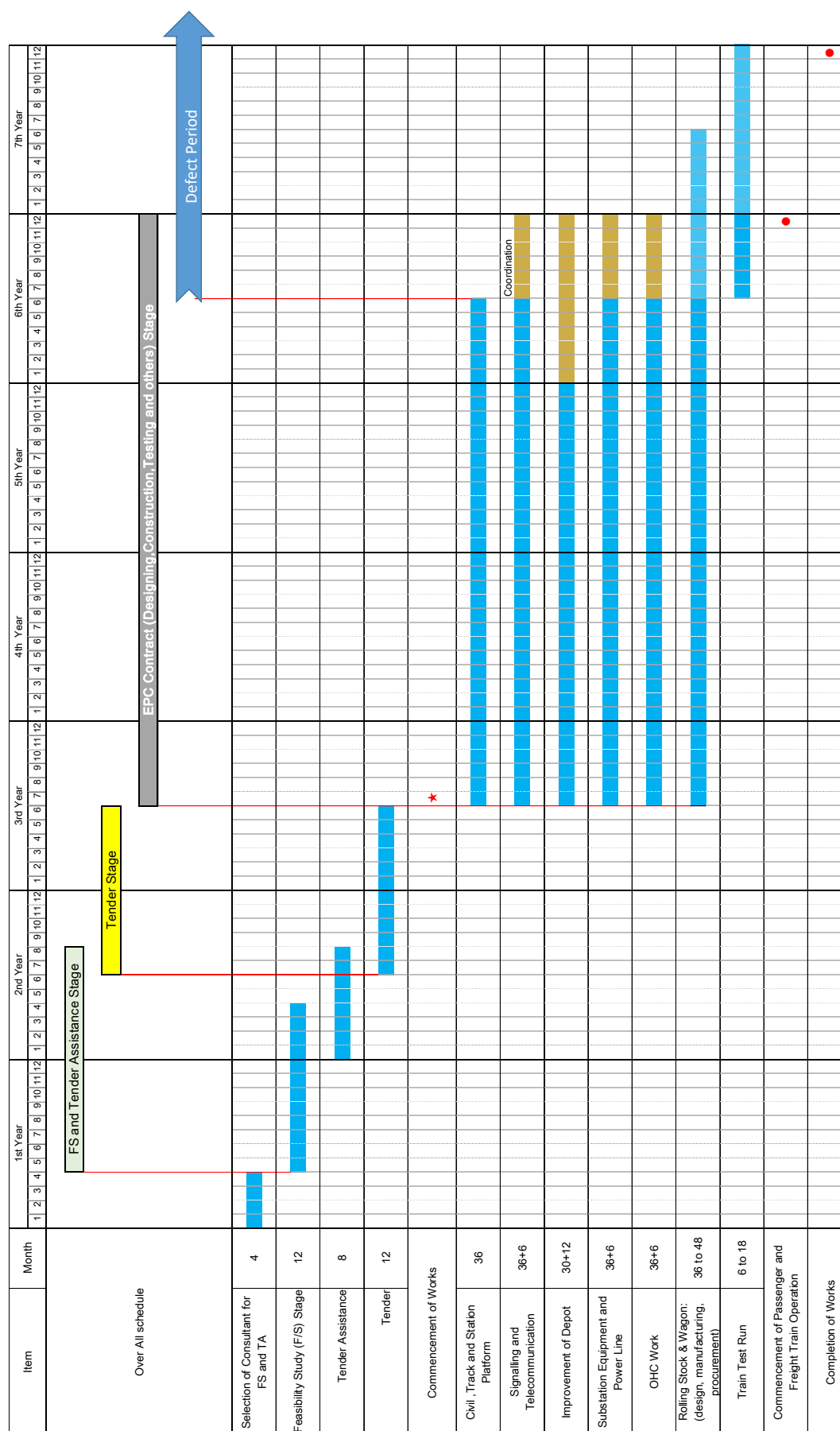


Figure 7-1 Project Implementation Schedule

8. The Advantages of Japanese Companies

Areas where Japanese companies have an advantage include rolling stock (electric locomotives and Electric Multiple Unit, EMU), electrical materials of substations, signals, and equipment in the depot and workshop.

8.1 Rolling Stocks (Electric Locomotives and EMU)

Most of the main rolling stocks currently are diesel-electric locomotives equipped with Chinese manufactured diesel engines used to rotate the generator. However, due to maintenance issues for motors of these locomotives, replacing the motor with a Russian manufactured one is now underway. Thus, the RA is recognizing the issues regarding the quality of existing locomotives. On the other hand, Japanese companies have high reliability in the railway system, and in the past, Turkmenistan government officials including the president himself have experienced the trains in Japan. In the meetings, there were indications that RA wants to introduce Japanese locomotives and Japanese companies have certain advantages in electric locomotives and EMUs.

However, in Turkmenistan, the GOST (GOSudarstvennyy STandart, осударственный стандарт) standard used in CIS countries is applied, and it is anticipated that certification of the standard will take time and money if Japanese manufactured locomotives are introduced. In addition, transporting the products will be costly as well as time consuming.

In order to improve the price advantage and to meet CIS standards, use of the main components such as inverters from Japanese companies and assembling the locomotives in a third country that have a track record of introducing them to CIS countries should be considered. In recent years, Japanese companies have set up production systems overseas and are promoting cooperation with overseas companies, therefore, it is possible to utilize those production lines. It is also a good idea to discuss with the RA and propose introducing Japanese standards.

8.2 Equipment of Receiving Substation

As described in Section 4.6.4, electrification of railways requires the use of single-phase (two-phase) power, which is rarely used outside of electrified railways. Many countries, including those in the CIS, use two phases out of the three alternately to obtain single-phase power. In this case, however, a three-phase imbalance may occur, which may violate the regulations of the power companies. Therefore, this study proposes transformers such as ‘Scott Connection Transformer’, ‘Scalene Scott Connection Transformer’, ‘Modified Woodbridge Connection Transformer’, ‘Roof Delta Connection Transformer’ etc. Japanese companies have certain advantages regarding these transformers.

In the case of a single track, there is a possibility that trains are unevenly distributed in a specific section. In that case, it is assumed that the three-phase imbalance does not meet the standards of the power

company even if the above transformer is used. As a countermeasure, there is a method of installing a compensator. Japanese companies have significant experience in Railway Static Power Conditioner (RPC).

A Japanese company has the price competitiveness for ultra-high voltage and extra high voltage disconnectors. In addition, other Japanese companies also have significant experience for gas insulated switchgear (GIS), which is expected to be introduced in urban areas.

8.3 Signalling

Present signaling system has been aged and the RA has expressed its intention to upgrade the signaling system along with electrification. In the case of full renewal of the system, there is room for Japanese companies to introduce their system, however, there are several issues. Replacement of the on-board equipment in the rolling stocks is required. The new signaling system needs to establish an interface with existing signaling systems of connecting lines. It also needs to function under weather conditions (temperature, daytime temperature differences, humidity, wind, sandstorms etc.) of Turkmenistan. These are barriers for the Japanese companies to participate. As in mentioned earlier of other components, required time and cost of adapting the GOST standard is also an issue.

8.4 Equipment for Depot / Workshop

As for the depot equipment, when introducing Japanese manufactured locomotives, it is necessary to introduce inspection equipment, therefore, it is possible to have some advantages as set with Japanese manufactured locomotives.

9. Issues and Action Plans for Realization

9.1 Comprehensive and Detailed Technical Study and Preparation for Financing

The size of the investment is large even only for the first stage and therefore, it requires multiple sources of financing. It is necessary to conduct a comprehensive and detailed technical study which will lead to the lending conditions of each finance lender. At present, even if a technical study is underway by the Asian Development Bank (ADB), it is desirable to conduct more detailed studies using other sources such as JICA's cost sharing technical cooperation in collaboration with ADB. Regarding the points which require additional investigation are described in each chapter, the following points are assumed as examples.

In case of future demand forecasting, to grasp the future transit demand and import / export trend, it is necessary to study international cargo flow patterns and future trends based on development trends in neighbouring countries and the entire Central Asia region.

Regarding the operation plan, at present a train operation table and diagram includes number of trains entering and leaving the depots and workshops is not available, so a simple operation plan should be prepared based on the number of trains in operation on main line per day for each section. In the future, it is necessary to formulate a detailed operation plan based on the operation table and diagram.

To understand the condition of the track and the civil engineering work items, it is necessary to scrutinize the points to be improved with a thorough investigation along the entire section of the first stage. If improvement is required and if a bridge or other structure needs to be improved or newly constructed, geotechnical tests and surveying will also be required. It is also necessary to examine for all the facilities at passenger and cargo stations.

A detailed study of the condition of depots and workshops is required for all depots and workshops of the target section based on information such as the inspection system, repair system status, layout, usage condition and workers' skills etc.

Detailed information regarding the power system, signalling and telecommunications need to be re-examined based on the present situation, weather conditions, power receiving conditions, etc.

For the rolling stocks, it is necessary to determine detailed specifications based on the operation plan, taking into account the participation of Japanese companies.

Regarding environmental and social considerations, the RA stated that the land for the railway is secured with a sufficient width, so it is considered that land acquisition will not be necessary in this study. However, it is necessary to confirm whether sufficient land is secured in case of access road construction, partial double line construction, in urban areas and involuntary resettlement is necessary. In addition,

implementation of the project also requires completion of the EIA in accordance with the provisions of Turkmenistan and the financing institutions.

9.2 Financing

As described in Chapter 6, it is difficult to carry out the first stage of the project with a single financing institution, so it is necessary to combine multiple financial resources, including the Turkmenistan national government budget. Considering the interests and loan conditions of the ECAs and MDBs, it is necessary to provide the necessary information to the lenders to make a loan decision through the above-mentioned technical study points. In addition to individual consultations between Turkmenistan and each ECAs and MDBs, discussions between three and four parties will also be necessary in order to adjust the scale, timing and scope of each financing institutions to ensure smooth project implementation.

The RA will take the initiative in consulting with the lenders and withdrawal of the financing from the lenders and the assistance from the Turkmenistan's national budget will be essential for sustainable railway operation.

9.3 Improvement of Financial Condition of the RA

It is necessary to improve the financial conditions of the RA to attract the lending conditions for lenders. At present, even though the RA is operating with profit, it but cannot withstand large-scale investments. For this reason, the revenue can be expected to increase by reviewing the tariff system in addition to the support from the central government. In addition, it is desirable to improve the financial position by reducing unnecessary spending.

9.4 Technical Discussion with Related Organizations

The implementation of the project will require the support of the cabinet ministers in charge of the RA.

For electrification, it is necessary to consult with the Ministry of Energy and Turkmenenergo in order to adjust the conditions for receiving power and financial burdens on facilities those can be useful to the electric power companies. Therefore, some initial investment of the RA can be reduced. It is also necessary to discuss with these organizations to modify the electricity tariff based on present situation.

It is necessary to consult and coordinate with the road management organizations (for both central and local governments) regarding the road and grade separated intersection construction in order to remove the level crossings for introducing high speed railway. It should be noted that if the grade separated structures do not progress as planned, it is necessary to reduce the traveling speed drastically in that section and, as a result, the benefits of the project will be limited.

9.5 Establishment of Maintenance system (Rolling Stocks and Tracks)

In order to realize a high speed railway, serious operation and maintenance (O&M) of the track is required. In addition to equipment and funds for operation and maintenance, human resource development is also required. Since human resource development takes time, it is necessary to start the preparation early. For introducing a high speed railway, it is desirable to establish a track maintenance and O&M system utilizing JICA's cost-sharing technical cooperation program to utilize Japanese technology.

9.6 Revision of Technical Standards

In Turkmenistan, technical standards have not been really updated since independence. For example, for electrification, the distance between substations is uniformly set at 70 km, however, in the case of AT feeder system, it is technically possible to make the interval between substations longer. But there is no such provision in current standards. In addition, in the case of the GOST standard, the number of companies who can participate is limited, so it is desirable to revise the technical standards so that more companies can participate.

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報告書の題名 トルクメニスタン国における鉄道近代化事業（英語）

Railway Modernization Project in Turkmenistan

委託事業名

令和元年度質の高いインフラの海外展開に向けた事業実施可能性調査事業

受注事業者名 株式会社オリエンタルコンサルティンググローバル

頁	図表番号	タイトル
2-7	Table 2-1	Major Earthquakes around Turkmenistan (M6.0 or higher)
3-5	Table 3-1	Cargo Handling Volume by Product Type in 2018 (Unit thousand Ton)
3-10	Table 3-2	Specifications for Current Track Structure and Track
3-14	Table 3-3	Number of Turnout Location between Major Stations
3-14	Table 3-4	Curve Radius of the Alignment between Turkmenabat - Turkmenbasy
3-14	Table 3-5	Gradient between Turkmenbat - Ashgabat - Turkmenbasy
3-24	Table 3-6	Number of Locomotives under the RA
3-25	Table 3-7	Inspection Type and its Frequency
3-26	Table 3-8	Rolling Stock Type for each Depot/Workshop
4-3	Table 4-1	Future Total GDP of Turkmenistan and Neighbouring Countries (2010 constant), billion USD)
4-6	Table 4-3	List of the Factories Constructed by the Japanese Companies
4-9	Table 4-4	Cargo Demand Forecast between Turkmenbasy and
4-10	Table 4-5	Future Passenger Demand Forecast between
5-2	Table 5-1	List of Conservation Areas in Turkmenistan
5-3	Table 5-2	Population composition ratio in Turkmenistan
5-11	Table 5-6	List of Environmentally Hazardous types of Economic and Other Activities
2-1	Figure 2-1	Population and Population Growth Rate
2-2	Figure 2-2	Constant GDP and Constan GDP Growth Rate
2-2	Figure 2-3	Sector wise GDP in Current Price
2-3	Figure 2-4	Consumer Price Index (CPI)
2-4	Figure 2-5	Power Plants and Major Power Transmission Lines in Turkmenistan
2-5	Figure 2-6	Climate Classification of Turkmenistan
2-6	Figure 2-7	Precipitation and Average Temperature in Ashgabat
2-6	Figure 2-8	Major Earthquake Occurrence Points around Turkmenistan, M6.0 or higher
2-7	Figure 2-9	Major Locations of Active Faults around Turkmenistan
3-1	Figure 3-1	Map of the Study Route
3-2	Figure 3-2	Organization Chart of the Railway Agency of Turkmenistan
3-3	Figure 3-3	Cargo Handling Volume from 2015 to 2018
3-3	Figure 3-4	Monthly Fluctuation of Cargo Transportation in 2018

(様式 2)

3-4	Figure 3-5	Cargo Handling Volume by Product Type in 2018
3-5	Figure 3-6	Number of Passenger Transported by Railway (2015 - 2019)
3-6	Figure 3-7	Daily No. of Train by Section in 2019
3-8	Figure 3-8	Construction Gauge for Non-Electrified Section
3-9	Figure 3-9	Standard Cross Section
3-12	Figure 3-12	Ballast Quarry Location Map
3-18	Figure 3-20	Clearance under the Overpass near Ashgabat Station
3-25	Figure 3-26	Most Common Locomotives using in Turkmenistan
4-3	Figure 4-1	Future Population Forecast of Turkmenistan
4-7	Figure 4-3	Product Wise Non-transit Cargo Demand of 2025 from
4-7	Figure 4-4	Product Wise Non-transit Cargo Demand of 2025 from