MYANMA RAILWAYS
MINISTRY OF TRANSPORT AND COMMUNICATIONS
THE REPUBLIC OF THE UNION OF MYANMAR

PREPARATORY SURVEY FOR YANGON-MANDALAY RAILWAY IMPROVEMENT PROJECT PHASE II

FINAL REPORT (FOR DISCLOSURE)

FEBRUARY 2018

JAPAN INTERNATIONAL COOPERATION AGENCY

ORIENTAL CONSULTANTS GLOBAL CO., LTD.
JAPAN INTERNATIONAL CONSULTANTS FOR TRANSPORTATION CO., LTD.
PACIFIC CONSULTANTS CO., LTD.
TONICHI ENGINEERING CONSULTANTS, INC.
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(Exchange Rate: October 2017)

1 USD=110 JPY

1 USD=1,360MMK

1 MMK=0.0809 JPY

Preparatory Survey for Yangon-Mandalay Improvement Project Phase II

Final Report

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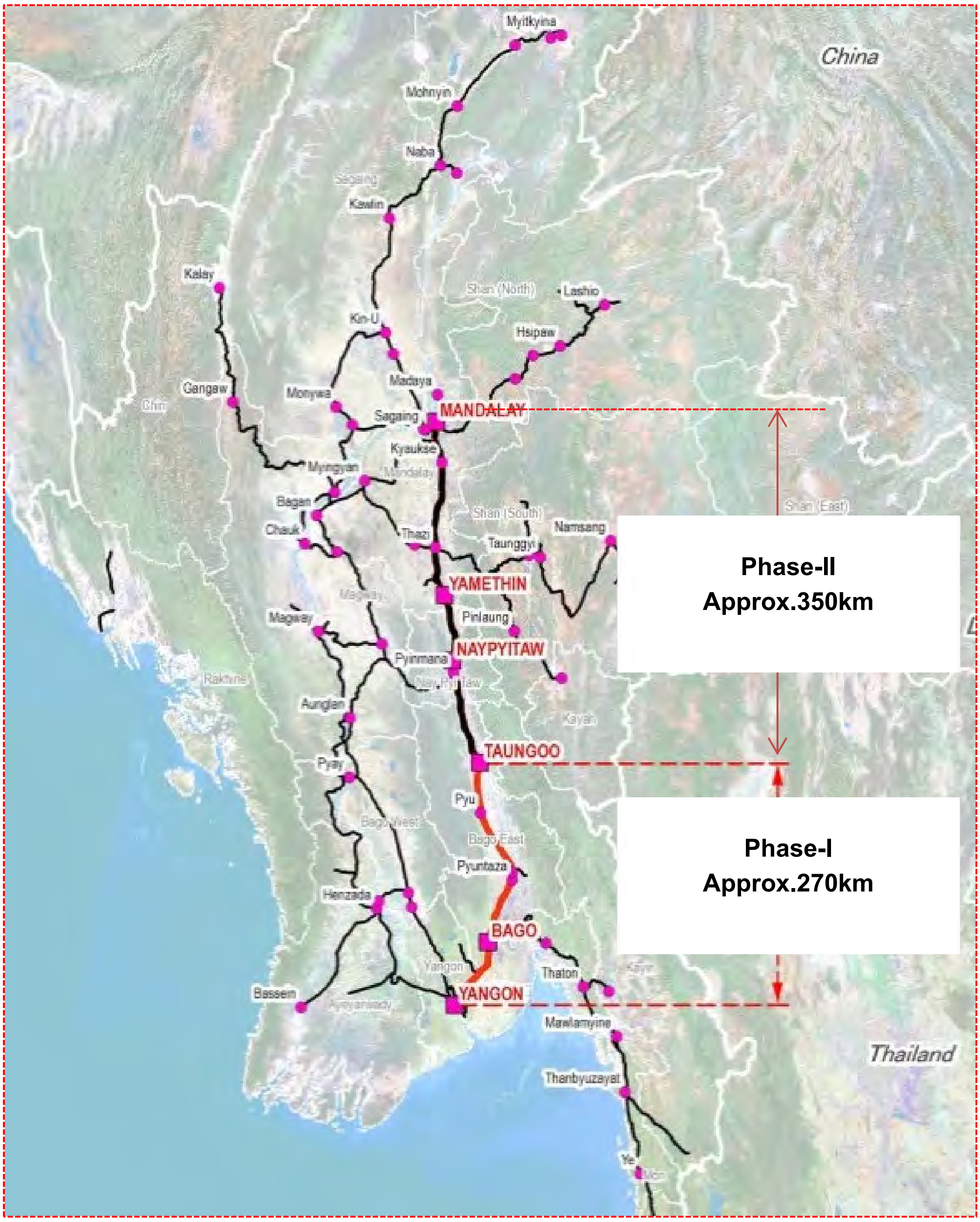
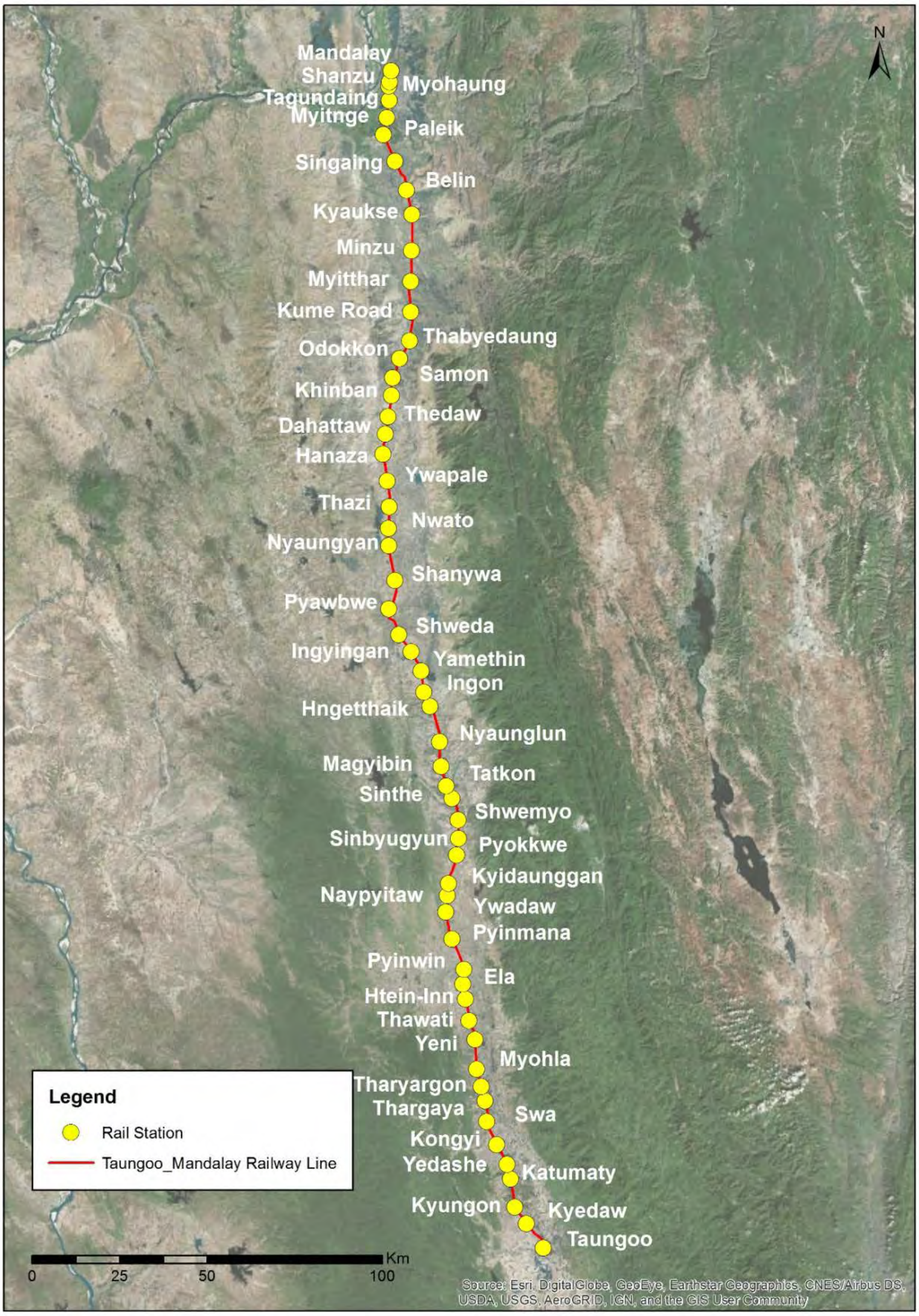


Republic of the Union of Myanmar



Source: JICA Study Team

Station Location Map of Yangon-Mandalay Railway

Abbreviations

No.	Abbreviation	English
1	AASHTO	American Association of State Highway and Transportation
2	AB	Absolute Block System
3	ABS	Automatic Block System
4	AC	Alternating Current
5	ACSR	Aluminium Conductors Steel Reinforced
6	ADB	Asian Development Bank
7	ADPC	Asia Disaster Reduction Center
8	AEC	ASEAN Economic Community
9	ARAP	Abbreviated Resettlement Action. Plan
10	AREMA	American Railway Engineering and Maintenance Way Association
11	ARP	Abbreviated Resettlement Plan
12	ASEAN	Association of South-East Asian Nations
13	ASTM	American Society for Testiong and Materials
14	ATP	Automatic Train Protection
15	ATS-S	Automatic Train Stop using S-type transponder
16	AVR	Automatic Voltage Regulator
17	AW	Added Weight
18	BD	Basic Design
19	BOD	Biochemical Oxygen Demand
20	BOT	Build Operate Transfer
21	BRT	Bus Rapid Transit
22	BS	British Standard
23	CBD	Central Business District
24	CBR	California Bearing Ratio
25	COD	Chemical Oxygen Demand
26	CS	Construction Supervision
27	CSU	Continuous Speed Unit
28	CTF	Cable Termination Frame
29	CTS	Centralized Train Supervision
30	CWDM	Coarse Wavelength Division Multiplexing
31	CWR	Continuous Welded Rail
32	DB	Dispute Board
33	DC	Direct Current
34	DD	Detail Design
35	DEL	Diesel Electric Locomotive
36	DEMU	Diesel- Electric Multiple Unit
37	DL	Diesel Locomotive
38	DMH	Department of Meteorology and Hydrology, Myanmar
39	DMS	Detailed Measurement Survey
40	DMU	Diesel Multiple Unit

No.	Abbreviation	English
41	DRC	Diesel Rail Car
42	DWIR	Drectorate of Water Resources and Improvement of River System
43	E&M	Electrical and Mechanical
44	ECC	Environmental Compliance Certificate
45	ECD	Environmental Conservation Department
46	EG	Emergency Generator
47	EI	Electronic Interlocking
48	EIA	Environmental Impact Assessment
49	EIT	End of intermediate transition curve
50	EMoP	Environmental Monitoring Plan
51	EMP	Environmental Management Plan
52	EN	European Standard
53	ESE	Electricity Supply Enterprise
54	ETC	End of Transition Curve
55	F/S	Feasibility Study
56	FC	Ferrule Connector
57	FC	Freight Car
58	FOB	Foot Over Bridge
59	FRP	Fiber-Reinforced Plastics
60	FWD	Falling Weight Deflectometer
61	GAD	General Administration Department
62	GDP	Gross Domestic Product
63	GL	Ground Level
64	GM	General Manager
65	GOJ	Government of Japan
66	GOM	Government of Myanmar
67	GPS	Global Positioning System
68	GRDP	Gross Regional Domestic Product
69	HF	High Frequency
70	HID	High Intensity Discharge Lamp
71	HT	High Tension
72	ICB	International Competitive Bidding
73	IEE	Initial Environmental Examination
74	I/F	Interface
75	IMF	International Monetary Fund
76	JBIC	Japan Bank for International Cooperation
77	JETRO	Japan External Trade Organization
78	JICA	Japan International Cooperation Agency
79	JIS	Japanese Industrial Standards
80	JNR	Japanese National Railways
81	JST	JICA study team
82	KLN	Kerry Logistics Network

No.	Abbreviation	English
83	LC	Level Crossing
84	LED	Light Emitting Diode
85	LO	Lubricating Oil
86	LRT	Light Rail Transit
87	LTE	Long Term Evolution(high speed wireless communication standard)
88	MARS	Multi Access seat Reservation System
89	MD	Managing Director
90	MDB	Multilateral Development Bank
91	MEC	Myanmar Earthquake Commitee
92	MEPE	Myanmar Electric Power Enterprise
93	MESC	Mandalay Electricity Supply Corporation
94	METI	Ministry of Economy, Trade and Industry
95	MGS	Myanmar Geosciences Society
96	MIMU	Myanmar Information Management Unit
97	ML	Main Line
98	MLIT	Ministry of Land, Infrastructure, Transport and Tourism, Japan
99	MM	Main Motor
100	MMI	Man Machine Interface
101	MMK	Myanmar Kyat
102	MNBC	Myanmar National Building Codes
103	MOALI	Ministry of Agriculture, Livestock and Irrigation
104	MOC	Ministry of Construction
105	MONREC	Ministry of Natural Resourse and Environmental Conservation
106	MOTC	Ministry of Transportation and Communicatoins
107	MPPE	Myanmar Petroleum Product Enterprise
108	MR	Myanma Railways
109	MSH	Main Signal House
110	MYT	Myanmar’s National Transport Master Plan
111	NEQ	National Environmental Quality Guidelines
112	NLTC	Non-on-load Tap Changer
113	NTP	Notice to Proceed
114	O&M	Operation & Maintenance
115	OCC	Operation Control Center
116	OCC Project	The Project for Installation of Operation Control Centre System and Safety Equipment
117	OCHA	United Nations Office for Coordination of Humanitarian Affairs
118	ODA	Official Development Assistance
119	OECD	Organization for Economic Co-operation and Development
120	OFC	Optical Fiber Cable
121	OLTC	
122	OTC	Overhead Traveling Crane
123	OTDR	Optical Time Domain Reflectometer

No.	Abbreviation	English
124	P/Q	Pre-Qualification
125	PAPs	Project Affected Persons
126	PAUs	Project Affected Units
127	PC	Prestressed Concrete
128	PGA	Peak Ground Acceleration
129	PGD	Peak Ground Displacement
130	PGV	Peak Ground Velocity
131	PMU	Project Management Unit
132	PPP	Public-Private Partnership
133	PSHA	Probabilistic Seismic Hazard Analysis
134	PIS	Passenger Information System
135	PVC	Poly Vinyl Chloride
136	PWM	Pulse Width Modulation
137	QA and QC Plan	Quality Assurance and Quality Control Plan
138	RBE	Rail Bus Engine
139	RC	Reinforced Concrete
140	Rf	Rectifier
141	RGL	Resources Group Logistics
142	RH	Relay Hut
143	RI	Relay Interlocking
144	ROB	Road Over Bridge
145	ROW	Right of Way
146	SA	Spectal Acceleration
147	SAC	Spaced Aerial Cable
148	SBD	Standard Bidding Documents
149	SC	Scissors crossing
150	SDR	Social Discount Rate
151	SIL	Safety Integrity Level
152	SL	Survey Center line
153	SM	Single Mode
154	SPAD	Signal Passed At Danger
155	SPT	Standard Penetration Test
156	SSI	Solid State Interlocking
157	STEP	Special Terms for Economic Partnership
158	STM	Synchronous Transfer Mode
159	SW	Switch
160	T/C	Technical Committee
161	TA	Tender Assistance
162	TAC	Technical Advisory Committee
163	TCL	Transition Curve Length
164	TEU	Twenty Foot Equivalent Unit

No.	Abbreviation	English
165	TID	Train Information Display
166	TMS	Train Monitoring System
167	TN	Turnout
168	T-N	Total Nitrogen
169	TOD	Transit Oriented Development
170	T-P	Total Phosphorus
171	TRS	Ticket Reservation System
172	UHF	Ultra High Frequency
173	UIC	International Union of Railways
174	UPS	Uninterruptible Power Supply
175	VAT	Value Added Tax
176	VHF	Very High Frequency
177	VR	Variable Resistance
178	YCDC	Yangon City Development Committee
179	YCR	Yangon Circular Railway
180	YCR-F/S	Feasibility Study of the Yangon Circular Railway Line Upgrading Project
181	YCR-MR/BD	Supporting Consulting Services for the Yangon Circular Railway Upgrading Project (for MR Works)
182	YCR-RS/BD	Basic Design Study of the Yangon Circular Railway Line Upgrading Project
183	YESC	Yangon Electricity Supply Corporation
184	YM	Yangon-Mandalay Railway
185	YM-D/D(1)	Detailed Design for Yangon-Mandalay Railway Improvement Project Phase I
186	YM(1)-F/S	Feasibility Study on the Rehabilitation and Modernization of Yangon–Mandalay Railway
187	YUTRA	Comprehensive Urban Transport Master Plan of the Greater Yangon

Station Name (Phase I)

NO	STATION NAME	KILOPOST	MILEAGE
1	Yangon	0	0
2	Pazundaung	1.61	1
3	Mahlwagon	4.02	2.5
4	Thin gan gyun	7.24	4.5
5	Toegyaungkalay	11.67	7.25
6	Ywathagyi	20.52	12.75
7	Laydaungkan	25.75	16
8	Darbain	36.15	22.46
9	Tongyi	48.68	30.25
10	Kyauktan	55.12	34.25
11	Tawa	61.56	38.25
12	Payathonzu	68.4	42.5
13	Bago	74.83	46.5
14	Shwele	83.24	51.72
15	Payagyi	91.73	57
16	Pyinbongyi	104.12	64.7
17	Kadok	114.26	71
18	Paungdawthi	121.91	75.75
19	Eimshaylayse	126	78.75
20	Daiku	130.76	81.25
21	Pyuntaza	141.22	87.75
22	Nyaung le bin	149.27	97.47
23	Tawwi	156.86	97.47
24	Pein za lok	163.75	101.75
25	Tha tegon	170.59	106
26	Kyauktaga	175.02	108.75
27	Penwegon	183.87	114.25
28	Taw gywe in	191.51	119

NO	STATION NAME	KILOPOST	MILEAGE
29	Kanyutk win	199.08	123.7
30	Nyaung bintha	206.8	128.5
31	Pyu	216.05	134.25
32	Zeya wadi	222.49	138.25
33	Nyaungchidauk	230.54	143.25
34	Kywebwe	240.19	149.25
35	Banbwegon	245.83	152.75
36	Oktwin	254.68	158.25
37	Thaung dai gon	260.31	161.75
38	Taungoo	267.15	166

Station Name (Phase II)

NO	STATION NAME	KILOPOST	MILEAGE
38	Taungoo	267.15	166
39	Kyedaw	276.5	171-3/4
40	Kyungon	282.5	175-1/2
41	Kaytumadi	290.5	180-1/2
42	Yedashe	295	183-1/4
43	Kongyi	301.5	187
44	Swa	308.5	191-1/2
45	Thargaya	314.5	195-1/2
46	Tharyargon	318.5	197-23/24
47	Myohla	324	201-1/4
48	Yeni	332.5	206-1/2
49	Tawuti	338	210
50	Hteininn	344.5	214
51	Ela	349	216-3/4
52	Pyiwin	353.5	219-1/4
53	Pyinmana	362	225
54	Ywadaw	370	230
55	Naypyitaw	370	232
56	Kyidaunggkan	378.5	235-1/4
57	Pyokkwe	387	240-1/2
58	Sinbyugyun	392	243-1/2
59	Shwemyo	397	246-3/4
60	Sinthe	404	251
61	Tatkon	407.5	253-1/2
62	Magyibin	414	257-1/2
63	Nyaunglun	420.5	261-1/2
64	Hngetthaik	431	268
65	Ingon	435.5	270-3/4

NO	STATION NAME	KILOPOST	MILEAGE
66	Yamethin(YMA)	441.5	274-1/2
67	Ingyigan	448	278-1/2
68	Shweda	454	282-1/2
69	Pyawbwe	462.5	287-1/2
70	Shanywa	471	292-3/4
71	Nyaungyan	481	299-1/4
72	Nwato	486	302-1/4
73	Thazi	492.5	306
74	Ywapale	499.5	310-1/2
75	Hanza	507.5	315-1/2
76	Dahattaw	512	318-1/4
77	Thedaw	517	322-1/4
78	Khinban	523.5	325-3/4
79	Samon	530	329
80	Odokkon	534.5	332-1/2
81	Thabyedaung	541	336-1/4
82	Kume Road	549.5	341-1/2
83	Myitthar	558.5	347
84	Minzu	567	352-1/2
85	Kyaukse	578	359-1/4
86	Belin	585	363-1/2
87	Singaing	594	369
88	Paleik	602	374-1/4
89	Myitnge	607	377-3/4
90	Tagundaing	611.5	380-1/2
91	Myohaung	616	382-3/4
92	Shanzu	617.5	384
93	Mandalay	620.5	385-1/2

Chapter 1 Introduction

1.1 Background of the Project

Source: JICA Study Team

Photo 1.1.1 Long-distance trains

The Yangon-Mandalay Railway covers 620 km (2015) of the about 6,072 km railway network operated by Myanma Railways (MR), connecting Yangon, the country's former capital and largest city, Naypyitaw, the new capital, and Mandalay, the second largest city.

The Line is a double-track/non-electrified route with a total of 96 stations (including cargo stations). In 2007, with the double-tracking of the last single-track section between Kyaukse and Mandalay, the line became double-track end to end. With a new station opened in Naypyitaw in 2009, the line is becoming the most important railway of Myanmar, connecting three major cities.

The Yangon, Bago, and Mandalay areas connected by this Yangon-Mandalay Railway are home to 19.55 million people (2014), 37% of Myanmar's total population, making it the most important line of MR's railway network.

Despite the increase in demand for transportation of passengers and cargo by Yangon-Mandalay Railway, safe and stable train operation is getting more and more difficult, due to the lack of proper maintenance of railway facilities over decades, poorly maintained and deformed rails causing train accidents, and aged, decrepit bridges not allowing the engineer to gain speed and run at a decent speed. For those reasons, the leading role in land transportation is now taken by truckers. In particular, for passenger transportation, while an expressway bus takes only 11 to 12 hours to connect Yangon and Mandalay, the train takes as long as 14 hours or so.

To promote the economic development of Myanmar in the future, proper sharing of transportation needs by rail is indispensable. At the Myanmar Development Cooperation Forum held in January 2013, the Ministry of Railways and Transportation (MORT) gave top priority to the project to improve and modernize the railway connecting Yangon and Mandalay. In response, JICA carried out the Preparatory Study for the Development of a National Transportation and Traffic Program (Master Plan). The Myanmar government requested JICA to conduct a feasibility study (FS) for a project to improve and modernize the Yangon-Mandalay Railway, which is implemented accordingly.

The feasibility study concluded that the government should give top priority to a project to improve and modernize the arterial railway from the viewpoints of national economy and fiscal revenues. Accordingly, an ODA loan agreement for the Phase I project was concluded in September 2014 in order to renew and modernize the transportation facilities and equipment along the Yangon-Taungoo section of the Yangon- Mandalay railway. Regarding the Phase I project currently under way, the detailed design study has already been completed, and MR is currently procuring contractors

The Yangon-Mandalay Railway Improvement Project is in line with what both the Japanese government and Myanmar government aim at, i.e., “the support of infrastructure development necessary for sustainable economic growth”, one of the priority areas in Japan’s Policy for Economic Cooperation to Myanmar (April 2012) and the rapid development of basic economic infrastructure, as one of the major objectives of the “Economic Policy” (July 2016) of the National League for Democracy (NLD), which recently came to power in the country.

The Study was triggered by a request from the Minister of Transport and Communications of Myanmar to early complete the renovation of the Yangon-Mandalay Railway as a whole, defining the improvement of the Taungoo-Mandalay section as a Phase II project and prompting it as a study necessary for the examination of the Yangon-Mandalay Railway Improvement Project Phase II (the Project).

1.2 Purpose of the Project

The objectives of this project are to rehabilitate deteriorated infrastructures and relevant facilities of the existing railway between Yangon city and Mandalay city and modernize them to increase the safety and speed of train operation, to reduce transportation cost, and to increase passenger and freight transportation, which will all contribute to the national economic development and the betterment of quality of life of the residents. The proposed technical targets of this project are to achieve the maximum train running speed of 100 km/h safely and to provide the train operation service of less than 8 hours for the section from Yangon to Mandalay.

Outline of the Project is shown below:

1) Civil Works including track works, civil structures and station buildings
2) Upgrade of signalling and telecommunication system
3) Introduction of new rolling stocks (DEMU)
4) Improvement of Freight Facilities
5) Improvement of Passenger Service Equipment including Automatic Ticket Bending Machine

1.3 Purpose of the Study

The purpose of the Study is to conduct studies and collect data such the purpose, outline, project cost, implementation schedule, implementation methods (procurement and construction), project implementation system, operation and management systems, environmental and social considerations, etc. for the review to implement the Project as a Japanese yen loan project.

1.4 Study Area

The subject of the Study is the 350 km section between Taungoo and Mandalay to be launched as the Yangon-Mandalay Railway Phase II project.

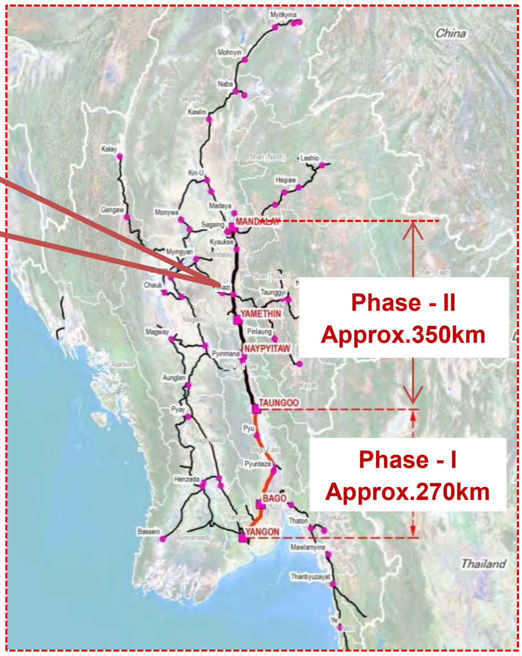
The outline of this section is as shown below::

< Outline of the Taungoo-Mandalay section >

- Distance: Approximately 350 km
- Number of stations: 56 stations
- Number of bridges: about 1,200
- Electrification method: non-electrified
- Number of lines: Double line

Source: JICA Study Team

Photo 1.4.1 Mandalay Station



Source: JICA Study Team

Figure 1.4.1 Location Map

1.5 Study Tasks

Tasks to be addressed in the study Tasks are as shown in Table 1.5.1.

Table 1.5.1 Study Tasks

No.	Study Tasks
[1]	Explain and Discuss the Inception Report to/with MR
[2]	Review and Update Existing Materials, Study Results, and Demand Forecasts
[2-1]	Review and Update Consistency with Existing Materials and Study Results
[2-2]	Review and Update Operation and Maintenance Plan
[2-3]	Review and Update Demand Forecasts
[2-4]	Examine Service Levels
[2-5]	Review the Project Plan for the Yangon-Mandalay Railway Improvement Project, Phase I
[3]	Study Natural Conditions; Study the Conditions of Existing Equipment and Facilities
[4]	Draft a Project Plan
[4-1]	Review the Route Plan
[4-2]	Develop a Civil Work and Facility Plan
[4-3]	Develop a Building and Equipment Plan
[4-4]	Develop Alignments and Track Layout Plan
[4-5]	Develop an Train Operation Plan
[4-6]	Develop a Rolling Stock Plan
[4-7]	Develop a Depot Plan
[4-8]	Develop a Freight Facilities and Container Transport Plan
[4-9]	Develop a Signalling and Telecommunication Plan
[4-10]	Develop an Electrical and Mechanical Plan
[4-11]	Develop a Station Development and Terminal Development Plan; Develop a Transport Nodes Improvement Plan
[4-12]	Develop a Project Plan
[4-13]	Develop a Financial Plan
[5]	Draft and Discuss an Interim Report I
[6]	Design the Project and Estimate the Cost for the Scope of Cooperation
[6-1]	Develop an Outline Design
[6-2]	Estimate the Project Cost
[7]	Develop a Project Implementation Plan for the Cooperation Scope
[7-1]	Examine the Procurement Plan and Method
[7-2]	Develop a Project Implementation Schedule
[7-3]	Review the Traffic Management Plan and the Safety Management Plan During the Construction Period
[7-4]	Review the Financial Plan
[7-5]	Develop a Project Implementation Plan
[7-6]	Examine the Scope of the Loan Assistance Project
[7-7]	Identify Points to be noted in developing the Project Work Plan
[7-8]	Examine Measures to Reduce the Project Cost and Shorten the Project Period
[8]	Review the Project Implementation System
[9]	Consider Environmental and Social Impact

No.	Study Tasks
[9-1]	Forecast and Evaluate Major Environmental and Social Impact; Develop Mitigation Measures; Draft Monitoring Plans
[9-2]	Help MR Develop Land Acquisition and Resettlement Action Plans
[10]	Evaluate the Effects of the Project
[10-1]	Verify the Effects of the Project Quantitatively
[10-2]	Verify the Effects Of the Project Qualitatively
[11]	Draft an Interim Report II and Discuss it with MR
[12]	Develop Visual Presentation Materials for the Project
[13]	Identify Points to be noted In carrying out the Project
[13-1]	Identify Points to be noted about the Unit and System to Manage and Maintain the Project
[13-2]	Identify Points to be noted and Develop Recommendations about the System to manage and maintain the Project
[13-3]	Streamline the Decision Making Process
[14]	Assist JICA in organizing relevant Seminars
[15]	Draft a Conclusion and Recommendations
[16]	Draft a Final Report and Discuss it with MR
[17]	Finalize a Final Report

Chapter 2 Review and Update Demand Forecast

2.1 Review of Demand Forecast in previous study

2.1.1 Precondition

Passenger and cargo demand forecast was conducted in YM(1)-F/S in 2014. The study is a part of MYT Conventional four-step traffic demand model was developed based on the result of traffic surveys (traffic count survey, roadside OD interview survey, terminal interview survey and transport operators survey) and secondary information, such as population and economic indicators in MYT. During modelling in the traffic demand forecast, the study area (the whole country) was divided into 71 traffic analysis zones. Future transportation network is assumed in MYT.

Preconditions in YM(1)-F/S are summarized as follows;

- Opening Year: 2023,
- Average Operation Speed (Passenger: Express): 81km/h,
- Average Operation Speed (Freight): 53km/h,
- Passenger Fare: 30MMK / km,
- Freight Rate: 36.5MMK / ton-km.

2.1.2 Demand Forecasting Result

Passenger and freight transport demand was estimated as follows in the YM(1)-F/S. The estimated passenger volume in 2023 and 2030 is 82,000 and 155,000 per day, respectively. The estimated cargo volume in 2023 and 2030 is 17,100 and 42,200 ton per day.

Table 2.1.1 Estimated Passenger Demand in YM(1)-F/S

(Unit: thousand passenger)

Year	Daily Boarding Passenger	Maximum Daily Sectional Passenger	Maximum Section
2023	82	43.5	Laydauntkan – Dabain
2030	155	80.0	Laydauntkan – Dabain

Source: YM(1)-F/S

Table 2.1.2 Estimated Cargo Demand in YM(1)-F/S

(Unit: thousand Ton)

Year	Daily Handling Cargo	Maximum Daily Sectional Cargo	Maximum Section
2023	17.1	17.1	Yangon - Taungoo
2030	42.2	42.4	Yangon - Taungoo

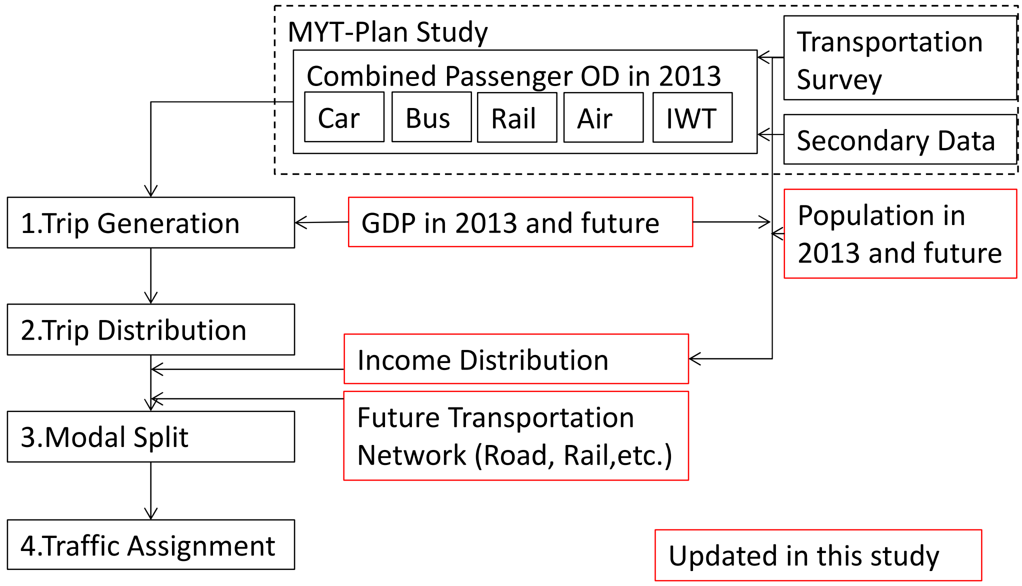
Source: YM(1)-F/S

2.2 Update of Demand Forecast

2.2.1 Methodology

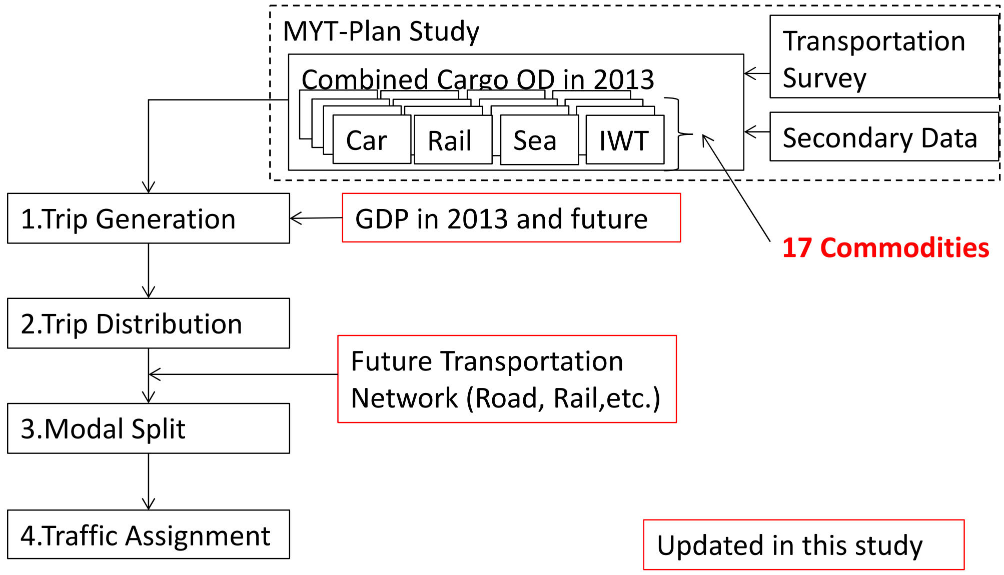
Four-step demand forecast model on passenger and cargo which was developed in MYT is adapted in this study. Considering the changes of precondition after the previous study, socio-economic frame and transportation network plan are reviewed in this study. Especially, following contents are updated;

- Population: Population Census 2014,
- GDRP: latest economic indicators,
- Highway development plan: truck ban policy for expressway , toll price, and
- Railway development plan: fuel cargo PPP project, dry port projects.



Source: JICA Study Team

Figure 2.2.1 Work FloSw for Passenger Demand Forecast



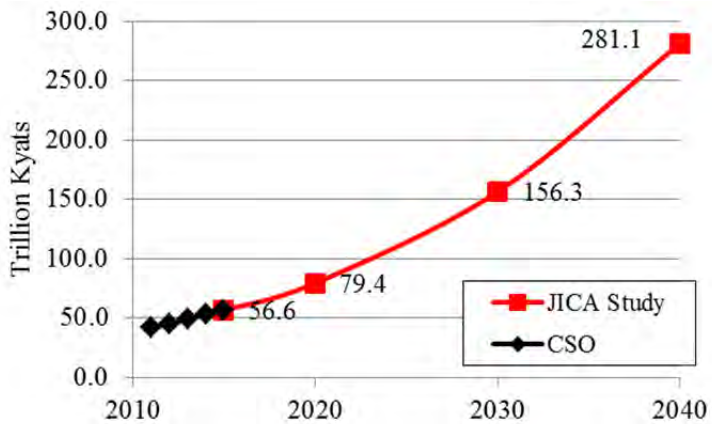
Source: JICA Study Team

Figure 2.2.2 Work Flow for Cargo Demand Forecast

2.2.2 Update of Socio-economic Frame

(1) GDP

Following table shows updated GRDP by state/region in this study. The GDP by region/state in 2015 is provided from Ministry of Finance and Planning. In the MYT, future annual economic growth is assumed 7.0% in average from 2011 to 2035, considering the past trend of high growth period in ASEAN countries. Also, the future distribution of GRDP in Myanmar, GDRP growth ratio by state/region, is decided considering spatial development plan in MYT. Those national economic growth ratio and distribution in MYT is adapted in this study. Due to the recent rapid growth of GDP in Myanmar, it is assumed that GDP growth after 2020 is slightly lower than the assumed growth ratio in MYT and is adjusted to be 7.0% in average from 2011 to 2035.



Source: Central Statistics Office (CSO) and JICA Study Team

Figure 2.2.3 GDP Projection (Whole Myanmar)

Table 2.2.1 Estimated GRDP by Region and State

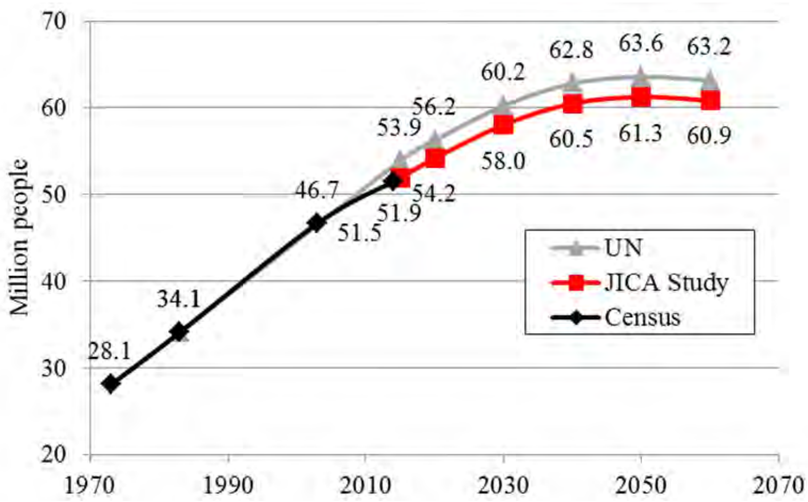
(Unit: Billion MMK: const. price 2010)

ID	State/Region	2015	2020	2030	2040
1	Kachin	1,101	1,612	3,438	6,184
2	Kayah	209	302	625	1,124
3	Kayin	1,078	1,591	3,438	6,183
4	Chin	209	275	469	844
5	Sagaing	6,982	8,569	12,033	21,643
6	Tanintharyi	2,031	2,879	5,781	10,397
7	Bago	4,913	6,924	13,750	24,730
8	Magway	5,321	6,564	9,376	16,863
9	Mandalay	6,331	9,680	22,188	39,907
10	Mon	2,391	3,480	7,344	13,209
11	Rakhine	2,033	3,172	7,500	13,490
12	Yangon	13,461	20,366	45,943	82,634
13	Shan	3,555	4,833	8,908	16,022
14	Ayeyawady	5,799	7,487	12,188	21,922
15	Naypyitaw	1,224	1,701	3,281	5,901
Total		56,636	79,435	156,262	281,053

Source: MoFP and JICA Study Team

(2) Population

"Myanmar Population and Housing Census" was conducted in 2014 and was opened to public the result in 2016. This is the first census in thirty years since 1987. Total population in whole Myanmar in 2014 is 50.3 million. Compared with estimated population in 2012 by Ministry of Immigration and Population, the actual population in whole Myanmar is smaller by around 10 million. With the census result, the future population growth ratio which is estimated with the assumed population growth ratio in "World Population Prospects: The 2015 Revision" United Nations and future population distribution estimated in MYT, future population distribution is updated as follows.



Source: Population and Household Census and JICA Study Team

Figure 2.2.4 Population Projection (Whole Myanmar)

Table 2.2.2 Estimated Population by Region and State

(Unit: thousand)

ID	State/Region	2014	2020	2030	2040
1	Kachin	1,689	1,702	1,689	1,617
2	Kayah	287	287	348	377
3	Kayin	1,574	1,574	1,892	2,047
4	Chin	479	479	528	546
5	Sagaing	5,325	5,325	5,810	5,933
6	Tanintharyi	1,408	1,408	1,770	1,965
7	Bago	4,867	4,867	5,746	6,155
8	Magway	3,917	3,917	4,678	5,045
9	Mandalay	6,166	6,166	6,843	7,064
10	Mon	2,054	2,054	2,827	3,278
11	Rakhine	3,189	3,189	3,384	3,387
12	Yangon	7,361	7,361	8,521	9,031
13	Shan	5,824	5,824	5,659	5,306
14	Ayeyawady	6,185	6,185	6,988	7,299
15	Naypyitaw	1,160	1,160	1,358	1,459
	Total	51,486	51,498	58,043	60,511

Source: Population and Household Census 2014 and JICA Study Team

(3) Income Level

1) GDP per Capita

Future GDP per capita in Myanmar is estimated with above mentioned estimated GDP and population. As shown in following table, it is estimated that GDP per capita will increase 4.4 times from 2015 to 2040. Annual average growth ratio is 5.7 to 7.0 % during the period.

Table 2.2.3 Estimated GDP per Capita

	Unit	2012	2015	2020	2030	2040
GDP/Capita	Thousand Kyats	891	1,091	1,480	2,769	4,821
AAGR*	%		7.0	6.3	6.5	5.7

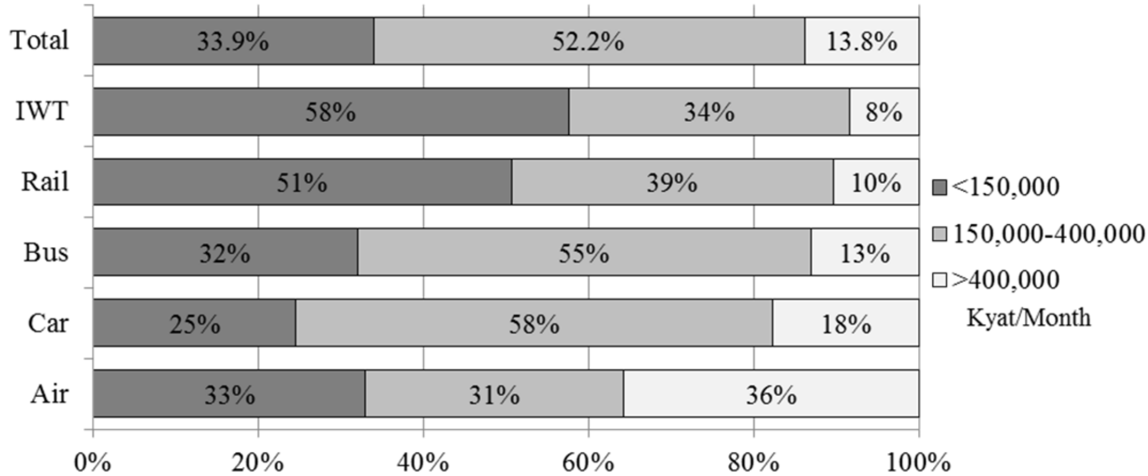
Note: Annual Average Growth Ratio

Source: JICA Study Team

2) Income Class Distribution

Household income distribution is interviewed to the travelers who crosses district boundary at the major terminals in Myanmar during MYT. Following figure shows the survey result.

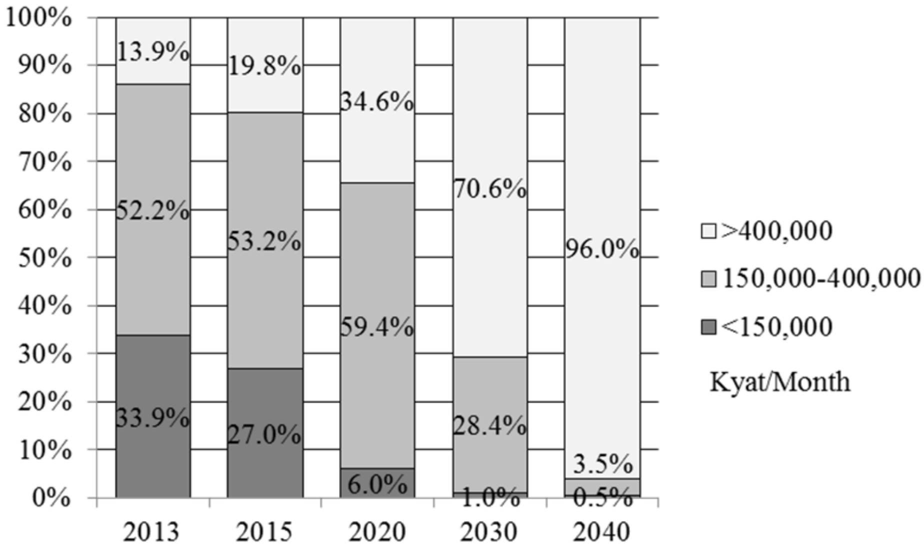
In total, 34% of travelers shares low income class, less than 150,000 kyat per month. 14% is high income class, more than 400,000 kyat per month. Remaining 52% are middle income class as of 2013.



Source: YM(1)-F/S

Figure 2.2.5 Household Income Distribution by Mode in 2013

With above mentioned growth ratio of GDP per capita in future, future distribution of the household income is estimated. As shown in following figure, it is estimated that high income class shares almost 70% and 96% in 2030 and 2040, respectively.



Source: JICA Study Team

Figure 2.2.6 Estimated Household Income Distribution

2.2.3 Update of Transportation Network

(1) Future Transportation Network

In MYT, future transportation development plan was established by 2030 as shown in following figure. In this study, the future transportation is assumed as the plans in MYT. Following plan is the key assumption for forecasting the demand for Yangon-Mandalay railway.

- Yangon - Mandalay Expressway opens for truck by 2023.
- Yangon Inner & Outer Ring Road open by 2030.
- Dry ports open at Ywarthargyi and Myitnge by 2023.

Additionally, it is assumed that fuel transportation shall be started by railway between Yangon and Mandalay based on the interview with MR.

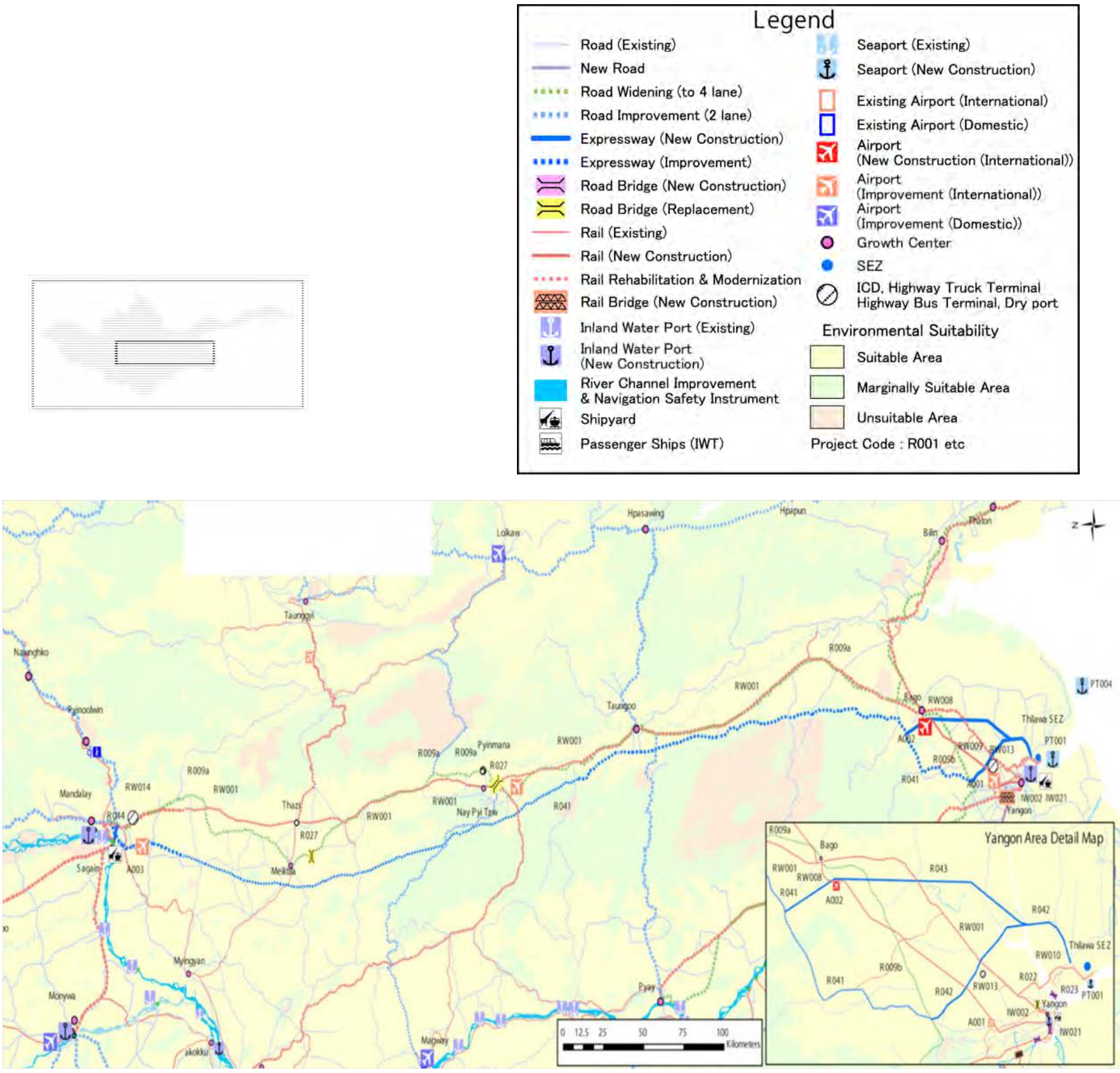
(2) Fare System for Yangon-Mandalay railway

1) Passenger

In YM(1)-F/S, three alternatives are studied for passenger fare system which is distance proportional system , namely 15 kyat/km, 30 kyat/km and 45 kyat/km. As a result, it is estimated that total fare-box revenue is maximize in 30kyat/km case and decided as 30 kyat/km.

2) Cargo

As of now, cargo train is charged 26.3 kyat/km and 39.4 kyat/km for general cargo and fuel cargo, respectively. In this study it is assumed same fare system is applied based on the discussion with MR.



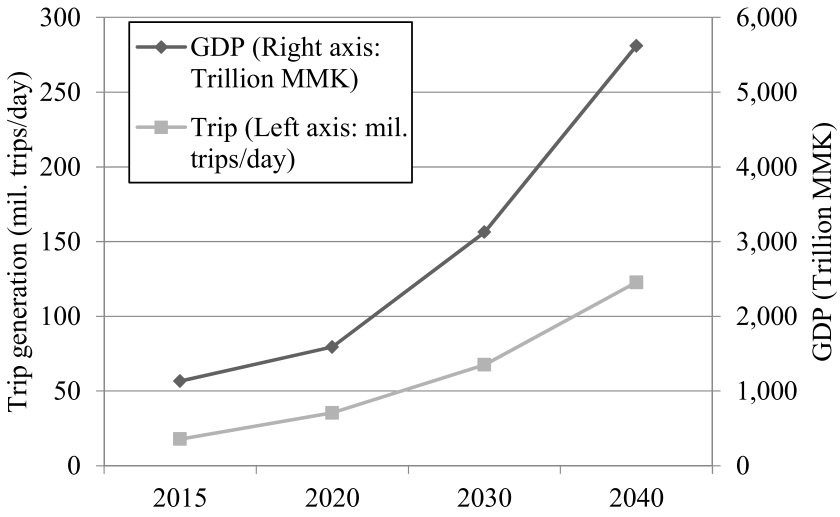
Source: JICA Study Team

Figure 2.2.7 Assumed Future Transportation Network along Yangon – Mandalay Railway

2.2.4 Update of Passenger Demand Forecast

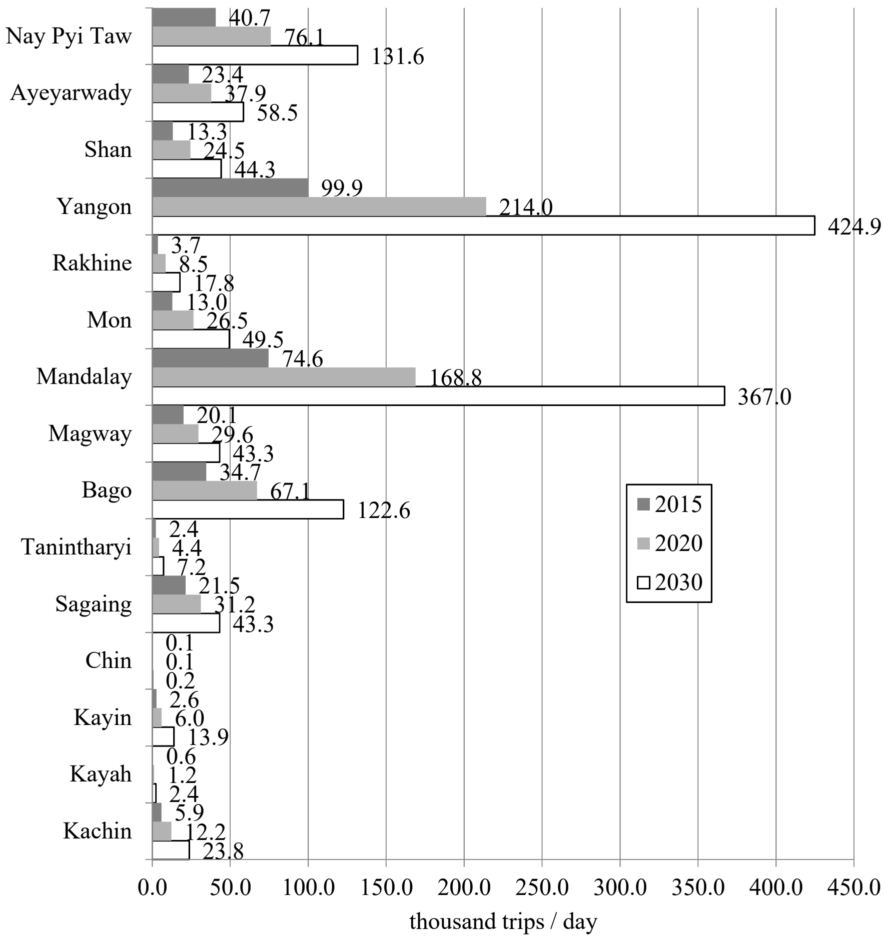
(1) Trip Generation

Population growth, economic development and improvement of income level affect the trip generation volume. In the MYT, considering examples of economic development and traffic growth in neighboring countries, the GDP elasticity of trip generation from each zone from 2013 to 2015 and from 2015 to 2030 were defined as 1.0 and 1.2, respectively. Total daily trip generation in 2013 is approximately 300 thousand. Daily trip generation in 2040 is estimated 2.4 million.



Source: JICA Study Team

Figure 2.2.8 Estimated Future Trip Generation in Myanmar



Source: JICA Study Team

Figure 2.2.9 Estimated Future Trip Generation by State/Region

(2) Trip Distribution

Future growth factor method, as shown in following formula, is applied to forecast future passenger OD as with the MYT.

$$T_{ij} = t_{ij} \cdot \frac{G_i}{g_i} \frac{A_j}{a_j} \cdot \frac{1}{2} \left(\frac{g_i}{\sum_j t_{ij} \cdot A_j / a_j} + \frac{a_j}{\sum_i t_{ij} \cdot G_i / g_i} \right)$$

where, T_{ij}: Future passenger distribution at zone i to j,

G_i: Future passenger production at zone i,

A_j: Future passenger attraction at zone j,

t_{ij}: Current passenger distribution at zone i to jl

g_i: Current passenger production at zone i, and

a_j: Current passenger attraction at zone j.

(3) Modal Split

Forecasted future trip is divided into each transport mode; air, private vehicle, bus and railway by using a multi-nominal logit model which was developed in YM(1)-F/S based on SP survey.

$$P_{ijk} = \frac{\exp U_{ijk}}{\sum_{k=1}^{n} \exp U_{ijk}}$$

Where:

$U_{ijk} = a \cdot time_{ijk} + b \cdot cost_{ijk} + Const.$

U_{ijk}: Utility of mode k between zone i to zone j,

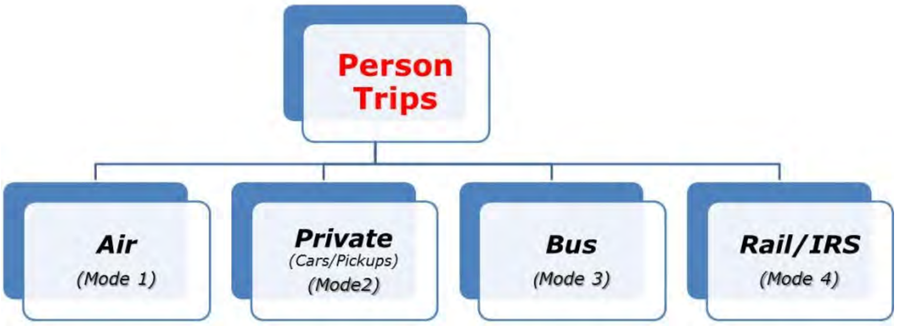
$time_{ijk}$: Travel time of mode k between zone i to j,

$cost_{ijk}$: Cost of mode k between zone i to j,

a and *b*: Parameter by Income Class,

Const.: Constant value

Travel Time is the total travel time including any waiting time, access time to the station and modal transfer. The cost includes the line haul cost as well as access cost to the station. In the case of a car, the cost includes any toll as well as the cost of the fuel.



Source: JICA Study Team

Figure 2.2.10 Modal Split Hierarchy

Table 2.2.4 Modal Choice Scale Parameters

Economic Activity Class	Calibration Parameters		Statistical Results		
			ρ2 [1]	t-value for each Parameter	
	a	b		a	b
1	-0.01382	-0.11256	0.523	-12.9914	-20.8532
2	-0.01172	-0.09427	0.431	-24.8334	-39.9602
3	-0.01169	-0.07192	0.20	-37.643	-42.9869

Source: JICA Study Team

(4) Passenger Demand Forecast

Following table shows the estimated future passenger share by transportation mode along the Yangon-Mandalay Railway for with/without Yangon-Mandalay railway improvement. With the improvement of Yangon-Mandalay railway, it is estimated that the share of railway increases from 13% to 15 % in 2030.

Table 2.2.5 Passenger Modal Share along Yangon-Mandalay Railway (Without Case)

(Unit: thousand Persons/day)

PAX	Air	Car	IWT	Rail	Bus	Total
2013	1.6	53.9	2.1	22.5	83.3	163.3
2023	18.6	173.6	0.6	65.4	180.6	438.7
2030	51.8	366.3	1.2	111.0	357.2	887.5
Share	Air	Car	IWT	Rail	Bus	Total
2013	1.0%	33.0%	1.3%	13.8%	51.0%	100%
2023	4.2%	39.6%	0.1%	14.9%	41.2%	100%
2030	5.8%	41.3%	0.1%	12.5%	40.2%	100%

Source: JICA Study Team

[1] This is the Correlation Coefficient, simply referred to by the Greek letter, ρ or Rho. ρ is a measure of goodness of fit. This statistical analysis was undertaken using the transport modelling software, STRADA. As reported in the text book, Modelling Transport and the A Self Instructing Course in Mode Choice Modelling: Multinomial and Nested Logit Models prepared by the US Department of Transport, a value of ρ^2 of 0.2 is acceptable and that greater than 0.4 is considered an excellent fit.

Table 2.2.6 Passenger Modal Share along Yangon-Mandalay Railway (With Case)

(Unit: thousand Persons/day)

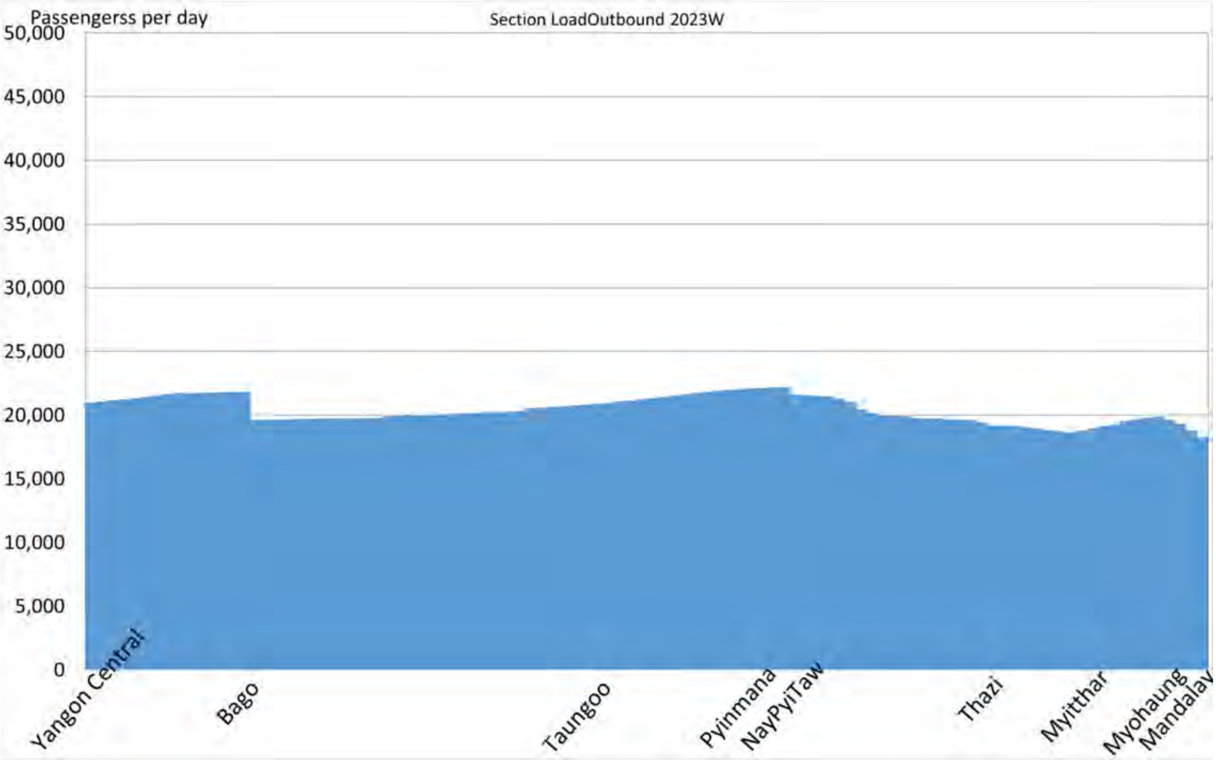
PAX	Air	Car	IWT	Rail	Bus	Total
2023	17.2	169.2	0.7	80.7	171.0	438.7
2030	49.5	357.7	1.3	132.4	346.6	887.5
Share	Air	Car	IWT	Rail	Bus	Total
2023	3.9%	38.6%	0.2%	18.4%	39.0%	100%
2030	5.6%	40.3%	0.1%	14.9%	39.1%	100%

Source: JICA Study Team

(5) Passenger Demand Forecast for Yangon-Mandalay Railway Line

Based on the above mentioned passenger demand forecast model, sectional passenger volume was estimated. It is estimate that total passenger volume in Yangon-Mandalay railway in 2023 and 2030 is 80,700 and 132,400 person per day, respectively. Maximum sectional traffic volume in 2030 is 78,600 passengers per both-ways per day between Ywadaw - Naypyitaw section.

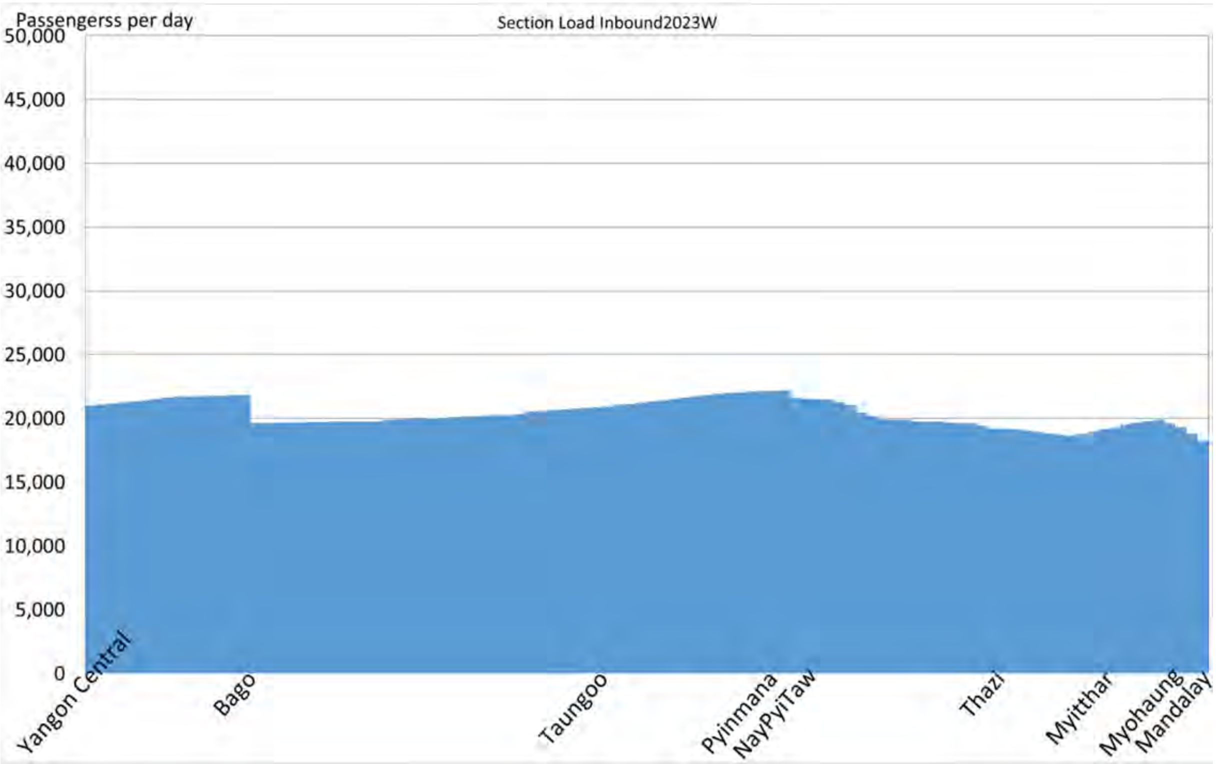
(Unit: passenger/day)



Source: JICA Study Team

Figure 2.2.11 Sectional Passenger Volume in 2023 (Outbound)

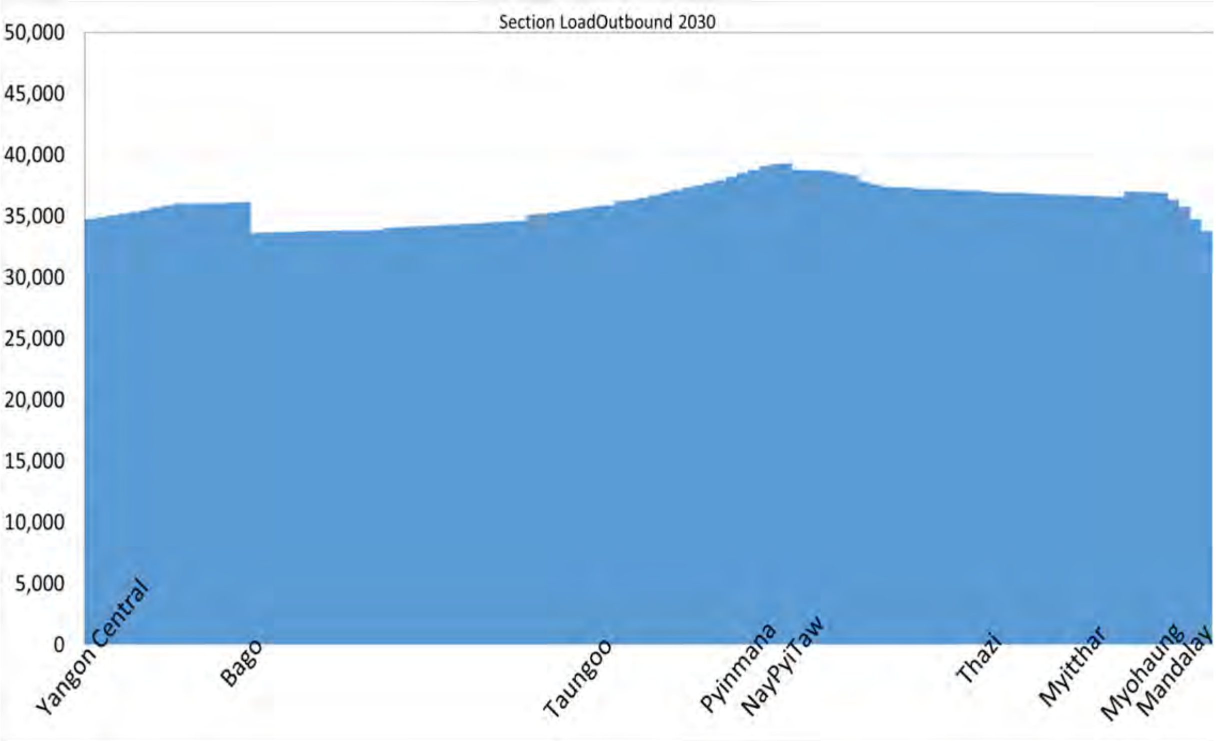
(Unit: passenger/day)



Source: JICA Study Team

Figure 2.2.12 Sectional Passenger Volume in 2023 (Inbound)

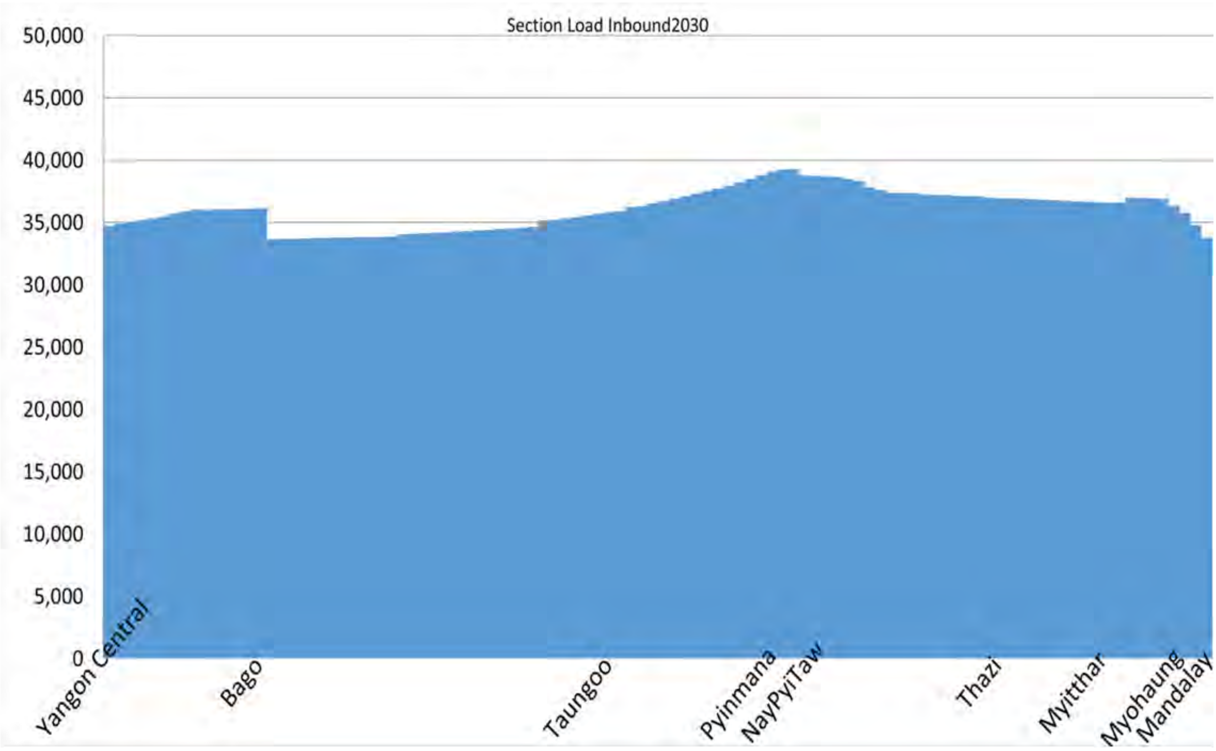
Unit: passenger/day)



Source: JICA Study Team

Figure 2.2.13 Sectional Passenger Volume in 2030 (Outbound)

(Unit: passenger/day)



Source: JICA Study Team

Figure 2.2.14 Sectional Passenger Volume in 2030 (Inbound)

2.2.5 Update of Cargo Demand Forecast

(1) Cargo Generation

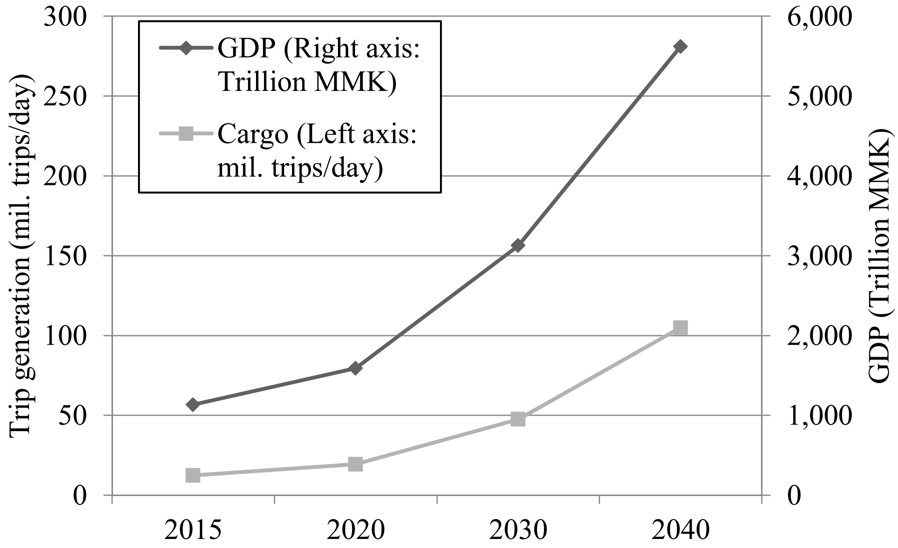
Future cargo generation in the whole Myanmar is estimated. The calculation method of the future cargo generation consists of two steps; a) control total which is the total domestic cargo volume of the whole Myanmar and b) zonal distribution which is the cargo production and attraction by traffic analysis zone.

1) Control Total

A control total is the total domestics cargo flow volume of all transport modes and all types of commodities, and is estimated by existing total domestics cargo flow volume and expansion factor calculated by future GDP growth rate and elasticity of domestic cargo volume to GDP.

In the MYT, elasticity of domestic cargo volume to GDP was calculated by the regression model in Japan during high-economic growth period (1960 - 1972) and is obtained at 1.342 (R^2 = 0.993).

Based on projected future GDP and elastic factor of domestic cargo flow, future domestic cargo volume in Myanmar is forecasted as shown in following figure. In 2040, total domestic cargo volume in Myanmar is expected to reach 2.1 million ton per year, 8.5 times of total domestic cargo in 2013.



Source: JICA Study Team

Figure 2.2.15 Estimated Future Domestics Cargo Volume in Myanmar

In the MYT, A control total by type of commodity was also estimated by elasticity of import/export volume to GDP in Thailand, Vietnam and Cambodia. The following table demonstrates defined elasticity factor, applied for the cargo generation in this study.

Table 2.2.7 Elasticity of EXIM Volume by Type Commodities

Commodity		Elasticity to GDP
1	Live Animal & Animal Products	1.22
2	Fish and Aquatic Products	1.76
3	Vegetable and Fruits	1.18
4	Grain and Grain Products	1.74
5	Other Agricultural Products (ex. Plantation Product)	2.13
6	Foodstuff, Beverage and Animal Food	1.30
7	Petroleum, Oil and Gas	1.84
8	Coal, Ore, Stone and Sand	2.21
9	Cement, Construction Material (incl. steel-frame)	1.93
10	Fertilizer (incl. Urea)	1.09
11	Garment, Textiles and fabric	1.24
12	Wood and Wood Products	1.14
13	Paper and Printed Matter	1.05
14	Metal and Metal Products (excl. construction material)	1.29
15	Industrial Material, Chemicals	1.33
16	Household articles, miscellaneous	1.80
17	Machinery and Parts, Transportation	1.40

Source: YM(1)-F/S

Based on the estimated control total of future domestic cargo volume and elasticity of each commodity to the GDP, future domestic cargo volume is forecasted by commodity type as shown in following table. As a result, major commodities which is transported in Myanmar, is construction material (388,000 ton per day), grain/grain products (350,700 ton), agricultural products (284,400 ton), petrol and gas (260,900 ton) in 2040.

Table 2.2.8 Forecasted Future Domestic Cargo Volume by Commodity in Myanmar

(Unit: thousand ton/day)

Commodity		2015	2020	2030	2040
1	Live Animal & Animal Products	1.8	2.4	4.4	7.0
2	Fish and Aquatic Products	3.2	5.1	12.8	28.0
3	Vegetable and Fruits	6.7	8.9	15.5	24.4
4	Grain and Grain Products	41.0	65.6	162.6	350.7
5	Other Agricultural Products (ex. Plantation Product)	18.7	33.8	106.4	284.4
6	Foodstuff, Beverage and Animal Food	29.0	40.3	75.7	127.5
7	Petroleum, Oil and Gas	26.3	43.4	114.4	260.9
8	Coal, Ore, Stone and Sand	10.6	19.6	65.0	181.3
9	Cement, Construction Material (incl. steel‐frame)	34.3	58.1	161.9	388.0
10	Fertilizer (incl. Urea)	15.7	20.4	33.3	49.8
11	Garment, Textiles and fabric	3.9	5.4	9.7	15.8
12	Wood and Wood Products	6.4	8.5	14.3	22.0
13	Paper and Printed Matter	1.6	2.1	3.3	4.8
14	Metal and Metal Products (excl. construction material)	2.6	3.7	6.8	11.5
15	Industrial Material, Chemicals	8.4	11.8	22.5	38.6
16	Household articles, miscellaneous	27.1	44.2	113.6	253.3
17	Machinery and Parts, Transportation	9.7	13.9	27.9	49.7
Total		247.1	387.2	950.2	2,097.6

Source: JICA Study Team

(2) Zonal Distribution

In MYT, based on estimated cargo production/attraction volume and zonal attribute, elasticity of cargo production/attraction to GRDP was calculated as shown in following table. Future cargo production and attraction is prepared by zone (Traffic Analysis Zone), adjusting to control total after computed by current cargo production and attraction, future GRDP by zone and elasticity of cargo production and attraction to GRDP.

Table 2.2.9 Elasticity of Domestic Cargo Production and Attraction to GRDP

	Cargo Production	Cargo Attraction
1 Live Animal & Animal Products	0.315	1.560
2 Fish and Aquatic Products	0.554	2.552
3 Vegetable and Fruits	0.803	0.819
4 Grain and Grain Products	1.274	0.771
5 Other Agricultural Products (ex. Plantation Product)	1.304	0.988
6 Foodstuff, Beverage and Animal Food	0.942	0.961
7 Petroleum, Oil and Gas	1.178	1.170
8 Coal, Ore, Stone and Sand	0.400	1.512
9 Cement, Construction Material (incl. steel - frame)	1.024	1.663
10 Fertilizer (incl. Urea)	1.663	1.831
11 Garment, Textiles and fabric	0.850	1.644
12 Wood and Wood Products	0.462	1.757
13 Paper and Printed Matter	0.858	0.579
14 Metal and Metal Products (excl. construction material)	1.621	0.384
15 Industrial Material, Chemicals	1.698	0.685
16 Household articles, miscellaneous	1.252	1.030
17 Machinery and Parts, Transportation	0.950	1.013

Source: YM(1)-F/S

1) Cargo Distribution

Future growth factor method, as shown in following formula, is applied to forecast future cargo OD by type of commodity.

$$T_{ij} = t_{ij} \cdot \frac{G_i}{g_i}\frac{A_j}{a_j} \cdot \frac{1}{2}\left(\frac{g_i}{\sum_j t_{ij} \cdot A_j / a_j} + \frac{a_j}{\sum_i t_{ij} \cdot G_i / g_i} \right)$$

where, T_{ij}: Future cargo distribution at zone i to j,

G_i: Future cargo production at zone i,

A_j: Future cargo attraction at zone j,

t_{ij}: Current cargo distribution at zone i to j,

g_i: Current cargo production at zone i, and

a_j: Current cargo attraction at zone j.

(3) Modal Split

Forecasted future cargo by type of commodity is divided into each transport mode; costal, inland water transport, railway and truck by using a logit model.

$$P_i = \frac{\exp(U_i)}{\exp(U_i) + \exp(U_j)}$$

where, $U_i = a \cdot time_i + b \cdot cost_i + Intercept$

$U_j = a \cdot time_j + b \cdot cost_j$

U_i: Utility of mode i,

$time_i$: Travel time of mode i,

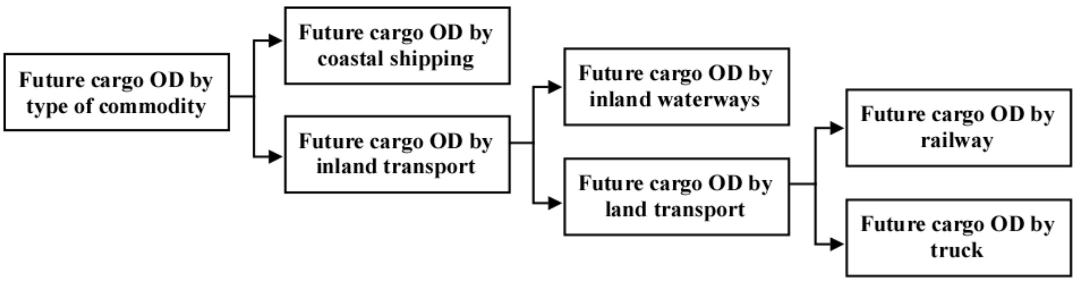
$cost_i$: Cost of mode i,

U_j: Utility of mode j,

$time_j$: Travel time of mode j, and

$cost_j$: Cost of mode j.

In the MYT, modal split model is developed by the three steps by type of commodity, applying the binary choice model, (i) coastal shipping - inland transport, (ii) inland waterways and land transport, and (iii) railway and truck.



Source: YM(1)-F/S

Figure 2.2.16 Binary Choice Type Modal Split Model

Following tables show estimated parameters for modal split model computed by current cargo OD by commodity and transport mode.

Table 2.2.10 Parameters for Modal Split Model 1 (Coastal - Land Transport)

Commodity	Intercept (Land Transport)	Time	Cost	R^2
COM01	-	-	-	-
COM02	-	-	-	-
COM03	-	-	-	-
COM04	-4.5860	-0.2244	-0.0001	0.8504
COM05	-	-	-	-
COM06	0.8766	-0.0004	-0.0004	0.7852
COM07	-	-	-	-
COM08	-	-	-	-
COM09	-10.8428	-0.2622	-0.0002	0.8223
COM10	-	-	-	-
COM11	-	-	-	-
COM12	-	-	-	-
COM13	-	-	-	-
COM14	-	-	-	-
COM15	-1.4294	-0.0858	-0.0004	0.5360
COM16	1.4364	-0.0355	-0.0004	0.5738
COM17	-9.1314	-0.0847	-0.0001	0.9584

Source: YM(1)-F/S

Table 2.2.11 Parameters for Modal Split Model 2 (IWT - Land Transport)

Commodity	Intercept (Land Transport)	Time	Cost	R^2
COM01	1.2754	-0.0314	0.0000	0.5787
COM02	2.3079	-0.0601	-0.0001	0.6536
COM03	3.7516	-0.0142	0.0000	0.4659
COM04	1.6748	-0.0194	-0.0001	0.4280
COM05	0.7821	-0.0158	-0.0001	0.6127
COM06	-0.4133	-0.0387	-0.0004	0.6713
COM07	-1.2808	-0.0386	-0.0008	0.6969
COM08	0.5921	-0.0741	-0.0006	0.9647
COM09	1.6728	-0.0087	-0.0003	0.5192
COM10	2.9320	-0.0283	-0.0003	0.4003
COM11	1.6906	-0.0219	-0.0004	0.5049
COM12	2.0427	-0.0169	-0.0004	0.9789
COM13	3.9057	-0.0172	-0.0003	0.6502
COM14	-1.1756	-0.0412	-0.0001	0.5042
COM15	-0.6727	-0.0732	-0.0006	0.7014
COM16	0.6300	-0.0173	-0.0001	0.5060
COM17	-0.1859	-0.0628	-0.0006	0.6602

Source: YM(1)-F/S

Table 2.2.12 Parameters for Modal Split Model 3 (Railway - Truck)

Commodity	Intercept(Truck)	Time	Cost	R^2
COM01	-	-	-	-
COM02	-	-	-	-
COM03	-	-	-	-
COM04	-0.8966	-0.3892	-0.0008	0.5338
COM05	-4.7785	-0.6994	-0.0015	0.5116
COM06	-0.7408	-0.2078	-0.0003	0.6553
COM07	-14.4599	-1.2397	-0.0026	0.6679
COM08	2.8238	-0.0121	-0.0001	0.5394
COM09	-3.0991	-0.1828	-0.0010	0.5839
COM10	1.4067	-0.1803	-0.0006	0.5132
COM11	-0.2128	-0.1772	-0.0010	0.5916
COM12	-16.5696	-0.5941	-0.0034	0.7840
COM13	-1.3076	-0.1718	-0.0012	0.5996
COM14	-9.2513	-0.6487	-0.0022	0.5597
COM15	-1.5760	-0.1760	-0.0008	0.5230
COM16	-1.9646	-0.5891	-0.0006	0.6127
COM17	2.5323	-0.0287	-0.0004	0.7430

Source: YM(1)-F/S

(4) Cargo Demand Forecast

Following table shows the result of estimated cargo share by transportation mode along the Yangon-Mandalay Railway for with/without Yangon-Mandalay railway improvement. With the improvement of Yangon-Mandalay railway, it is estimated that the share of railway increases from 5% to 11 % in 2030.

Table 2.2.13 Cargo Modal Share along Yangon-Mandalay Railway (Without Case)

(Unit: thousand ton/day)

Cargo Volume	Truck	Rail	IWT	Total
2013	79.2	5.4	5.5	90.1
2023	146.3	9.7	30.7	186.7
2030	294.5	17.2	68.2	379.9
Share	Truck	Rail	IWT	Total
2013	89.7%	6.0%	6.1%	100%
2023	78.4%	5.2%	16.4%	100%
2030	77.5%	4.5%	18.0%	100%

Source: JICA Study Team

Table 2.2.14 Cargo Modal Share along Yangon-Mandalay Railway (With Case)

(Unit: thousand ton/day)

Cargo Volume	Truck	Rail	IWT	Total
2023	135.1	20.9	30.7	186.7
2030	271.5	40.7	67.7	379.9
Share	Truck	Rail	IWT	Total
2023	72.4%	11.2%	16.4%	100%
2030	71.5%	10.7%	17.8%	100%

Source: JICA Study Team

(5) Cargo Demand Forecast for Yangon-Mandalay Railway Line

Based on the above mentioned freight demand forecast model, station to station cargo volume was estimated as follows. In the assignment process, it is assumed that bulk cargo and general cargo will be handled at Myohaung station and Myinge area in Mandalay area, respectively.

It is estimate that total cargo volume in Yangon-Mandalay railway in 2025 and 2030 is 30,000 and 41,000 ton per day, respectively.

Table 2.2.15 Station to Station Cargo Volume in 2025 (Outbound)

(Unit: ton/day)

Commodity		Yangon					Total
		Myohaung	Myinge	Thazi	Pyinmana	Taungoo	
1	Live Animal & Animal Products	0	0	0	0	0	0
2	Fish and Aquatic Products	0	0	0	0	0	0
3	Vegetable and Fruits	0	0	0	0	0	0
4	Grain and Grain Products	153	0	2	0	1	157
5	Other Agricultural Products (ex. Plantation Product)	0	199	0	1	1	201
6	Foodstuff, Beverage and Animal Food	0	1,068	137	93	23	1,321
7	Petroleum, Oil and Gas	5,177	0	0	0	0	5,177
8	Coal, Ore, Stone and Sand	18	0	3	6	0	26
9	Cement, Construction Material (incl. steel - frame)	5,672	0	186	21	65	5,944
10	Fertilizer (incl. Urea)	0	43	0	0	0	43
11	Garment, Textiles and fabric	0	54	0	0	0	54
12	Wood and Wood Products	0	120	0	0	0	120
13	Paper and Printed Matter	0	137	0	0	0	138
14	Metal and Metal Products (excl. construction material)	435	0	2	0	0	437
15	Industrial Material, Chemicals	0	866	28	34	4	931
16	Household articles, miscellaneous	0	142	2	4	3	151
17	Machinery and Parts, Transportation	0	80	1	6	1	88
Total		11,455	2,708	360	167	99	14,788

Source: JICA Study Team

Table 2.2.16 Station to Station Cargo Volume in 2025 (Inbound)

(Unit: ton/day)

Commodity		Myohaung	Myinge	Thazi	Pyinmana	Taungoo	Total
		Yangon					
1	Live Animal & Animal Products	0	0	0	0	0	0
2	Fish and Aquatic Products	0	0	0	0	0	0
3	Vegetable and Fruits	0	0	0	0	0	0
4	Grain and Grain Products	138	0	2	10	8	158
5	Other Agricultural Products (ex. Plantation Product)	0	444	0	1	2	447
6	Foodstuff, Beverage and Animal Food	0	442	24	47	27	540
7	Petroleum, Oil and Gas	564	0	0	0	0	564
8	Coal, Ore, Stone and Sand	151	0	0	9	83	244
9	Cement, Construction Material (incl. steel - frame)	231	0	27	54	24	336
10	Fertilizer (incl. Urea)	0	59	0	0	0	59
11	Garment, Textiles and fabric	0	75	2	0	0	76
12	Wood and Wood Products	0	2,375	11	4	577	2,967
13	Paper and Printed Matter	0	24	0	0	0	24
14	Metal and Metal Products (excl. construction material)	58	0	0	0	0	58
15	Industrial Material, Chemicals	0	880	3	5	2	890
16	Household articles, miscellaneous	0	68	0	1	3	72
17	Machinery and Parts, Transportation	0	18	0	0	0	18
Total		1,142	4,384	70	131	726	6,452

Source: JICA Study Team

Table 2.2.17 Station to Station Cargo Volume in 2030 (Outbound)

(Unit: ton/day)

Commodity		Yangon					Total
		Myohaung	Myinge	Thazi	Pyinmana	Taungoo	
1	Live Animal & Animal Products	0	0	0	0	0	0
2	Fish and Aquatic Products	0	0	0	0	0	0
3	Vegetable and Fruits	0	0	0	0	0	0
4	Grain and Grain Products	249	0	4	1	0	254
5	Other Agricultural Products (ex. Plantation Product)	0	358	0	1	0	359
6	Foodstuff, Beverage and Animal Food	0	1,863	247	120	19	2,249
7	Petroleum, Oil and Gas	10,183	0	0	0	0	10,183
8	Coal, Ore, Stone and Sand	54	0	4	12	0	69
9	Cement, Construction Material (incl. steel - frame)	13,183	0	246	26	29	13,484
10	Fertilizer (incl. Urea)	0	68	0	0	0	68
11	Garment, Textiles and fabric	0	90	0	0	0	91
12	Wood and Wood Products	0	155	0	0	0	155
13	Paper and Printed Matter	0	180	1	0	0	181
14	Metal and Metal Products (excl. construction material)	765	0	3	1	0	768
15	Industrial Material, Chemicals	0	1,319	52	16	0	1,387
16	Household articles, miscellaneous	0	268	2	5	2	278
17	Machinery and Parts, Transportation	0	121	2	6	1	129
Total		24,433	4,422	561	188	52	29,656

Source: JICA Study Team

Table 2.2.18 Station to Station Cargo Volume in 2030 (Inbound)

(Unit: ton/day)

2030		Myohaung	Myinge	Thazi	Pyinmana	Taungoo	Total
		Yangon					
1	Live Animal & Animal Products	0	0	0	0	0	0
2	Fish and Aquatic Products	0	0	0	0	0	0
3	Vegetable and Fruits	0	0	0	0	0	0
4	Grain and Grain Products	305		4	12	4	326
5	Other Agricultural Products (ex. Plantation Product)	0	977	0	1	0	979
6	Foodstuff, Beverage and Animal Food	0	710	31	55	19	815
7	Petroleum, Oil and Gas	2,618	0	0	0	0	2,618
8	Coal, Ore, Stone and Sand	416	0	1	18	169	605
9	Cement, Construction Material (incl. steel - frame)	293	0	76	6	7	381
10	Fertilizer (incl. Urea)	0	54	0	0	0	54
11	Garment, Textiles and fabric	0	84	3	0	0	87
12	Wood and Wood Products	0	3,724	11	3	158	3,896
13	Paper and Printed Matter	0	40	0	0	0	40
14	Metal and Metal Products (excl. construction material)	107	0	0	0	0	107
15	Industrial Material, Chemicals	0	1,542	2	2	1	1,546
16	Household articles, miscellaneous	0	118	0	0	2	121
17	Machinery and Parts, Transportation	0	32	0	0	0	32
Total		3,739	7,280	128	98	361	11,606

Source: JICA Study Team

Chapter 3 Natural Condition

3.1 Introduction

Below natural condition surveys for implementing a project for the improvement of the existing railway (Taungoo station to Mandalay station: approximately 350km) were conducted in this study.

(a) Climate

- Meteorological Data and Hydrological Data Collection
- Hydrological Survey

(b) Earthquake

(c) Geotechnical Conditions

The result of these natural condition surveys are described for reference of evaluation of study by each experts of JST , examination of additional surevey in next detailed desing stage and reference of design conditons in next detailed design stage.

3.2 Climate

3.2.1 Objective

The objective of the survey is to collect basic meteorological and hydrological information. The situation regarding the flooding occurred in the past around three locations selected by the Myanmar Railway Authority along the Taungoo-Mandalay Railway Track was collected from MR staffs or local resident peoples.

(1) Meteorological Data and Hydrological Data Collection

Meteorological data was collected from seven Meteorology and Hydrology stations along the Taungoo-Mandalay railway. These stations are Taungoo, Yamethin, Pyinmana, Tatkone, Meikhtila, Kyaukse and Mandalay.The Hydrological Data (Water Level) was collected from three major rivers stations.

- Taungoo: Sittoung River
- Myintnge: Dokehtawady River and
- Mandalay: Ayeyarwady River.

(2) Hydrological Survey

Hydrological Survey has two works.

- Interview Survey
- Water Level Survey

The surveyor interviewed local peoples to get the information of flood condition when the flood occurred by natural causes. And the surveyor surveyed the maximum water level height of the location confirmed in the interview survey.

3.2.2 Meteorokogical & Hydrological Date Collection

(1) Meteorological Data collection

1) Climate

Myanmar's Climate can be described as tropical monsoon climate. It is characterized by strong monsoon influences, has a considerable amount of sunshine, a high rate of rainfall, and high humidity that makes it sometimes feel quite uncomfortable.

2) Temperature (2006-2016)

The temperature and rainfall have been analyzed from 2006 to 2016 to understand the meteorological conditions of the project area and its surroundings along the Taungoo-Mandalay railway. The data was collected from seven stations, namely Mandalay, Kyaukse, Meiktila, Pyinmana, Tatkone, Yamethin and Taungoo.

Table 3.2.1 The Highest And Lowest Temperature (°C) In 7-Stations During (2006 To 2016)

Station Name	Month (max)	Highest Temp (avg) (°C)	Month (min)	Lowest Temp (avg) (°C)
Taungoo	Mar-May	40.0-44.0	Dec-Feb	10.0-12.5
Pyinmana	Mar-May	41.0-44.5	Dec-Feb	9.0-13.0
Tatkon	Mar-May	40.0-44.2	Dec-Feb	9.0-15.0
Yamethin	Mar-May	40.0-45.0	Dec-Feb	6.0-11.0
Meiktila	Mar-May	41.0-44.0	Dec-Feb	10.0-12.8
Kyaukse	Mar-May	40.5-43.2	Dec-Feb	8.4-10.0
Mandalay	Mar-May	42.2-45.0	Dec-Feb	10.5-12.3

3) Rainfall (2006-2016)

According the data of DMH, the least amount of rainfall occurs in Yamethin station and it was 94 mm in 2016. The annual highest amount of rainfall occurs in Taungoo station with 2244 mm in 2006. The proportion of annual rainfall has increased significantly in Taungoo station. The average amount of minimum rainfall for the whole 11-year period occurs in Yamethin station and it was 801.3mm. The average amount of maximum rainfall occurs in Taungoo station and it was 1919.5mm.

Table 3.2.2 The Highest And Lowest Rainfall (mm) In 7-Stations During (2006 To 2016)

Station Name	Month/year	Highest Rainfall (mm)	Month/year	Lowest Rainfall (mm)
Taungoo	Aug-09	859.0	May-09	1.0
Pyinmana	Sep-11	370.0	Jun-09	1.0
Tatkon	Apr-08	319.0	Jul-06	1.0
Yamethin	Sep-06	316.0	Aug-10	1.0
Meiktila	Oct-10	296.0	Oct-12	1.0
Kyaukse	Sep-13	326.0	May-14	1.0
Mandalay	Sep-06	450.0	1-Jul-17	1.0

Source: Google Maps

4) Cyclone

(a) Historical Records of Cyclone Paths & Cyclone Intensity (2006-2016)

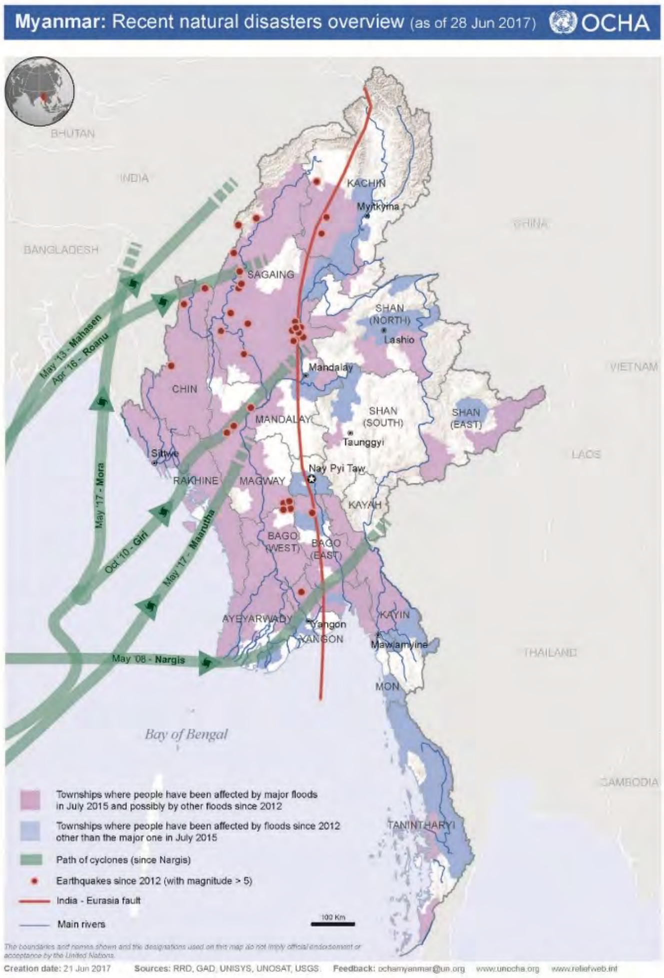
Cyclones are one of the most critical meteorological disasters, and considered the most significant natural disasters that take place in Myanmar. As shown in the following Figures, many cyclones have passed through Myanmar. Cyclone paths generally follow a southwest-to-northeast trajectory.

The following descriptions are the historical records of cyclones paths and intensity which has crossed Myanmar coast, and quoted from DMH and Wikipedia. Another source about the Cyclones Map was collected from the OCHA. The Map was updating in 2017 for the natural disasters overview as shown in the following Figure.

Table 3.2.3 Historical Records of Cyclone Paths & Cyclone Intensity(2006-2016)

Department Of Meteorology And Hydrology						
Historical Records of Cyclone Paths & Cyclone Intensity (2006-2016)						
Cyclone Type	**Date**		**Total Fatalities**	**Damage USD(mil,bil)**	**Highest Winds (km/h)**	**Affected Area**
	from	**to**				
MALA	April/24/2005	April/29/2006	37.0	$6.7 mil	185-220	Thailand, Myanmar
AKASH	May/14/2007	May/15/2007	14.0	$982 mil	85-120	Andaman, Nicobar, Myanmar, Bangladesh
SIDR	Nov/11/2007	Nov/16/2007	10000.0	$1.7 bil	215-260	India, Bangladesh, Myanmar
NARGIS	April 27, 2008	May 3, 2008	138366.0	$12.9 bil	165-215	Thailand, Myanmar,India, Bangladesh,Laos, Sri Lanka
BIJLI	April/14/2009	April/17/2009	4.0	-	75-95	Thailand, Myanmar, India, Laos, Sri Lanka
GIRI	Oct /21/2010	Oct /22/2010	157.0	$359 mil	195-250	Thailand, Myanmar, Bangladesh
MAHASEN	May/10/2013	May/16/2013	107.0	$5.14 mil	85.0	Thailand, Myanmar, Bangladesh, Laos, Sri Lanka
KOMEN	Jul/26/2015	Jul/30/2015	187-280	-	75-85	Myanmar, India, Bangladesh
ROANU	May/14/2016	May/22/2016	227.0	$1.7 bil	85-100	Myanmar,Sri Lanka, Bangladesh
KYANT	Oct/19/2016	Oct/30/2016	-	-	22.2	Myanmar,India, Bangladesh

Source: DMH



Source: DMH

Figure 3.2.1 Cyclone Track of MYANMAR (Since Nargis)

5) Flooding (Station between Taungoo and Mandalay) (2006-2016)

Flooding is another major natural disaster that takes place frequently in Myanmar during the rainy/monsoon season. As explained above, the corridor between Taungoo and Mandalay has commonly faced flooding problems and train operation has occasionally been disturbed.

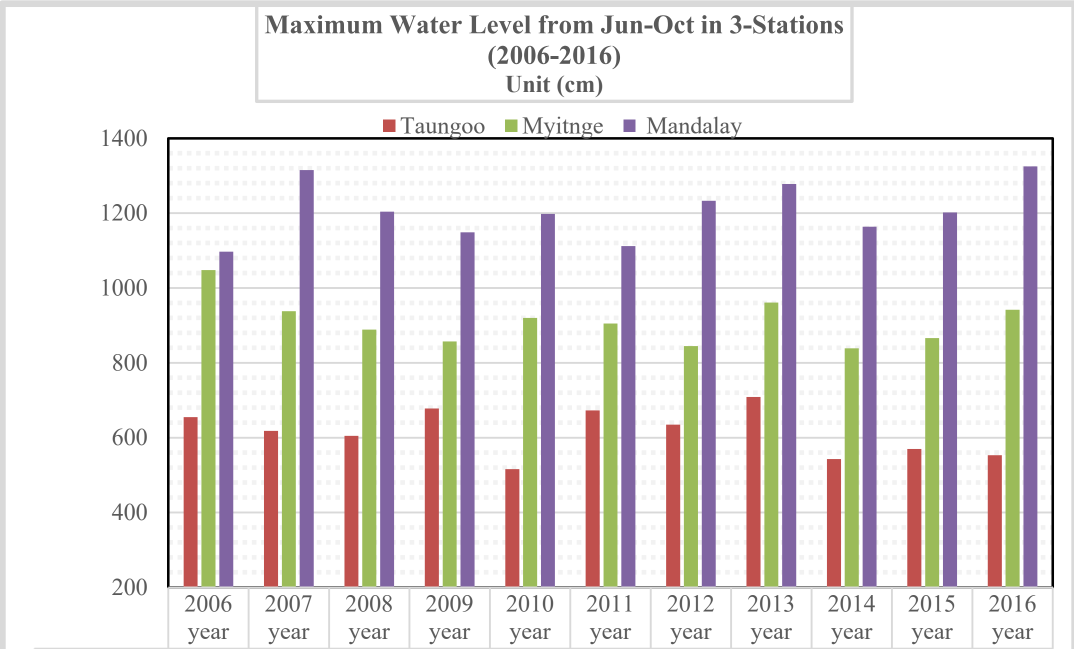
(a) Water Level and Rainfall during Flooding

There are three stations for the data collection of water level along the Taungoo-Mandalay railway track. These are Taungoo Station (Sittoung River), Myitnge Station (Dokehtawady River) and Mandalay Station (Ayeyarwaddy River). During in (2006 to 2016), the water level exceeding the dangerous level and weather condition of each stations recorded by the DMH are as shown in the following table.

Table 3.2.4 Historical Record of Water Level

Station :	Taungoo	Myitnge	Mandalay
River :	Sittoung	Dokehtawady	Ayeyarwady
Danger Level (cm) :	**600 cm**	**870 cm**	**1260 cm**
Maximum WL During 2006 to 2016	709 cm(2013)	1048 cm(2006)	1325 cm(2016)

Source: DMH Data



	2006 year	2007 year	2008 year	2009 year	2010 year	2011 year	2012 year	2013 year	2014 year	2015 year	2016 year
Taungoo	655	618	605	678	516	673	635	709	543	570	553
Myitnge	1048	938	889	857	920	905	845	961	839	866	942
Mandalay	1097	1315	1204	1149	1198	1112	1233	1278	1164	1202	1325

Source: DMH

Figure 3.2.2 Maximum Water Level in 3 stations

(b) Flood Situation along the railway track and station

The Taungoo-Mandalay railway corridor runs along the Sittoung River and crosses many major rivers such as Sinthay River, Samon River, Paalaung River, Zawgi River, Myintnge River (Dokehtawady River) and runs along/near many Canals and Dams. Therefore, the railway corridor has been suffering from outflow of water from the Rivers, Canals and Dams.

By the records of the DMH in 3-Meteorology and Hydrology stations, the flooding problems occurred nearly every years and Mandalay is the least. Myintnge station is the most effected in flooding problems during in 2006 to 2016. In Taungoo-Mandalay railway, the most effected of the flooding problems occurred between Thazi to Mandalay regions. So that Myanmar Railway Authority confirmed three locations for the Interview and Water Level Survey.

Along the Taungoo-Mandalay railway track the most flooding was occurred by the outflow of water from rivers and heavy raining in this area or water came down from upper. The railway stations in Taungoo to Mandalay are not affected more than the railway bridges or near of the bridges location.

(2) Hydrological Survey

Table 3.2.5 shows the three locations for interview and flood mark survey where were confirmed by the Myanmar Railway authority.

Table 3.2.5 Location of the Interview and Flood Mark Survey

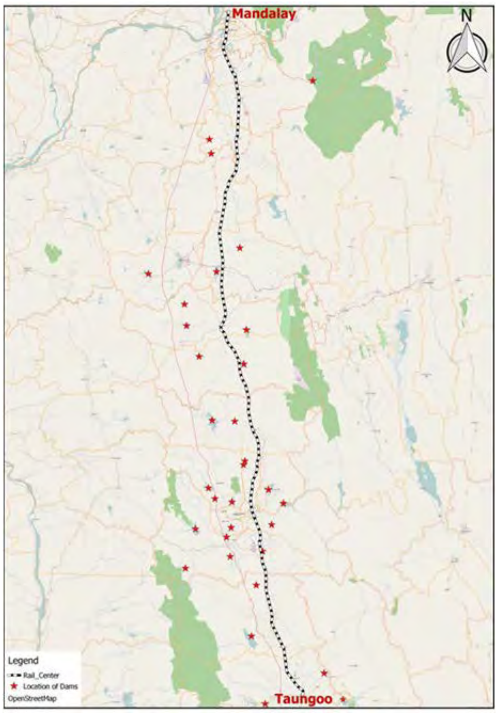
Ministry of Transport & Communications, Myanmar Railway
Yangon-Mandalay Railway Improvement Project, Phase (II), (2017-2018) Budget Year
Preliminary of Engineering (Metrological and Hydrogical)

Sr. No	Between Stations		Between Miles		Special Process	Remark
	From	Between	From	Between		
1	Tagontaing	Myit Nge	379/21	22	It was flooded and the frame aslo collapsed.There has	Tagontaing Station
					the big rock in the bridge of water-hole from	
					Taungthaman Lake.	
2	Thapyay Taung	Kumae	336/19	21	The water are flowing and the frame are eroded by the	Thapyay Taung Station
					water. So, there have some little valley likes a hole.	
3	Oohtokekone	Thapyay Taung	332/23	24	There was very serious flooded in Samone Chaung	Oohtokekone Station
					Bridge and the frame were broken.	

Source: Myanmar Railway

1) Dam Construction along the railway track

Dams are constructed for a specific purpose such as water supply, flood control, irrigation, navigation, sedimentation control, and hydropower. A dam is the cornerstone in the development and management of water resources development of a river basin. By the Irrigation Department data, the following Table shows the lists of dams which located along or near the Taungoo-Mandalay railway area.



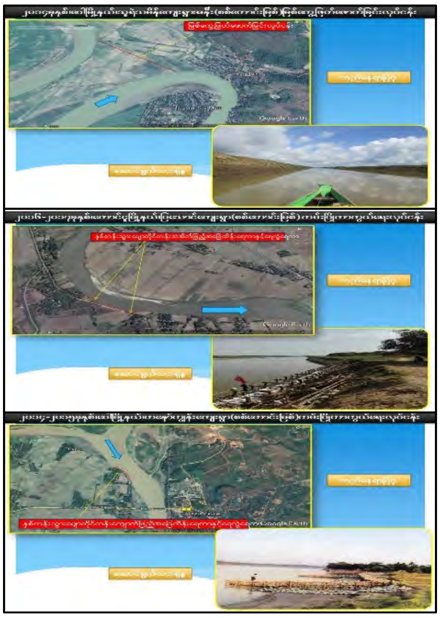
No.	Reservoir Dam/Diversion Dam/Detention Dam	Location	Information		Max Storage Amount (Acres Feet)	Horizontal Area (Acres)	Benefited Area (Acres)
		Township/Village	Height(ft)	Length(ft)			
	Bago Division						
1	Kanni Diversion Dam	Taungoo/Pain Ne Pin	14	212			2000
2	Seik Phu Taung Diversion Dam	Taungoo	8	120			
3	Pathi Dam	Taungoo/Kyauk Taing	90	2500	30500	930	4000
							(2*1.1) Mega Watt
4	Swar Creek Dam	Yedashe/U Yin Hmu	97	6600	228000	6900	35000
5	Chaung Ma Gyi (Myo Hla) Dam	Yedashe/Za Yit San	70	3600	9730	360	3000
	Nay Pyi Taw Council						
1	Yae Ni Diversion Dam	Lewe/Thapyay Kan	7	250			4200
2	Yan Aung Myin Dam	Lewe	63	4060	10460	830	3000
3	Thae Phyu Dam	Lewe/Yae Pyar Yoe	60	2650	8718	578	1200
4	Chaung Ma Nge Dam	Lewe/Pan Nyo San	96	2150	90770	3148	8000
							(50) Kilo Watt
5	Madan Dam	Lewe/Na Nwin	100	8305	36500	1113	8000
6	Chaung Ma Gyi (Pyin Mana) Dam	Pyin Mana/Kyet Su Ai	88	6000	40000	1400	
7	Paung Long Dam	Pyin Mana/Kawma	430	3100	560000	4199	35000
8	Paung Long Diversion Dam	Nay Pyi Taw/Pyin Mana	15	750			
9	Kinn Thar Dam	Tatkon/Kyaukse	40	1600	72	6	2000
10	Mone Chaung Dam	Tatkon/Kan Gyi	40	1530	500	40	4850
11	Sin Thay Dam	Tatkon/Mezali	109	1350	143000		32400
12	Sin Thay Diversion Dam	Tatkon	20	930			
13	Myo Hla (Tatkon) Dam	Tatkon/Myo Hla	80	2100	13000	465	3313
	Mandalay Division						
1	Le Phyu Detention Dam	Yamethin/Inn Taing	20	3190	245	25	6200
2	Yae Bote Chaung Dam	Yamethin/Yae Bote	25	3160	350	32	450
3	Thaphan Chaung Dam	Pyawbwe/Thaphan Chaung	63	2460	895	512	1200
4	Chaung Kauk Diversion Dam	Pyawbwe/Lethae Kyoe	8	300			
5	Chaung Kauk Dam	Pyawbwe/Lethae Kyoe	74	6800	12500	750	11500
6	Shan Ma Nge Dam	Meikhtila	89	6800	20630	1129	200
7	Sa Mone Detention Dam	Thazi/Htanaung Gone	38	14000	7913	2000	12000
8	Thet Taw Dam	Thazi/Kyay Kya	60	4460	15200	600	2500
9	Thapyay Yoe Dam	Wundwin/Taung Nyo	75	1150	7000	536	
10	Thit Tat Gone Diversion Dam	Myitthar/Thit Tat Gone	15	400			5000
11	Kin Tar Dam	Kyaukse/Kan Zwal	236	2034	873580	10720	201500
12	Myo Gyi Diversion Dam	Kyaukse/Taung Taw	6.5	160			4150

Source: MALI

Figure 3.2.3 Location of Dams along the Taungoo-Mandalay railway area and list of dams

2) River Improvement

The purposes of these projects were River Bank Protection, improvement of the old embankment, River Improvement data was collected from the DWIR in Bago Division and Mandalay Division to understand the River Dredging, Excavation and Improvement of River. In Bago Division, DWIR has 8-Locations for the River Improvement. Only two locations are near in Taungoo.



No.	River Name	Project Name	Project Type
1	Sittaung	Thuye Tha Main Village	Bend cutting for improvement of waterways and erosion protection
		Tanaw Kyun Village	Timber Spur with rocks inside
		Aung Chan Thar Ward Ohn Pin Village, Thayet Pin Village	Timber Spur with Sand Bags inside
		Phyu-Oak Pyart-Hmone Highway	Timber Spur with rocks inside
		19-Ward, Dawna Road	Timber Spur with rocks inside
		Aung Gyi Village	Timber Spur with Sand Bags inside
		Hlae Swae Myaung Village and Chaung Kyo Village	Timber Spur
		Pya Thaung Village	Timber Spur with Sand Bags inside
2	Dokehtawady	Thipaw Township	Steel Basket based Concrete embankment Improvement of old embankment
		Tha Bake Tan Village	Concrete embankment
		Banaw Village	Bore Pile based Concrete embankment
		Nyaung Pin Thar Village	Steel Basket based Concrete embankment
		Inlyar Village and Kinlat Village	Sand Bag based Concrete embankment
		Hpa Ye Kyun East and West Village	Steel Basket based Concrete embankment Sand Bag based Concrete embankment
3	Pannlong	Shwe Sar Yan Village	Steel Basket based Concrete embankment
		Taung Kin-Myauk Myay Ward	Steel Basket based Concrete embankment
		Myopyin Thet Taw Ya Pagoda East and Zawdika Sawmill front	Concrete embankment
		Innwa region	Steel Basket based Concrete embankment
		Oke Kyut Hpo Village	Steel Basket based Concrete embankment
		Ohn Let Kauk Village	Steel Basket based Concrete embankment
		Wonpatace Village	Steel Basket based Concrete embankment

Source: DWIR

Figure 3.2.4 21-Locations of River Improvement

In Mandalay Division, DWIR have 13-Locations for the River Improvement in Dokehtawady River and Pannlong River. The purposes of these projects were River Bank Protection and.

3.3 Earthquake

3.3.1 Background and Earthquake Zone of Myanmar

Among the natural disasters, an earthquake is one of the most destructive geological hazards that can cause damage, as there are primary effects by ground motion and ground failure, and other secondary effects such as tsunami, landslide, liquefaction and fire. Myanmar is more prone to earthquakes than other Indochina countries due to its seismological location. Tectonically, Myanmar lies in the frontier or convergence zone where two major plates, namely the India Plate (composed of the Indian continent and Indian Ocean) and the Eurasia Plate (comprising Europe, a part of Asia including the Eastern Highlands of Myanmar, and South China Sea) congregate. Sagaing fault has been suggested as the Plate boundary.

This is a tectonically active region and major active faults and fault systems are present almost all over of the country. Under the situation in Alpide earthquake Belt that is one of the two major earthquake belts, thrust transfers current collisional structures overwhelmed the whole country and devastating earthquakes struck the people and infrastructure of Myanmar

Apart from the Sagaing fault, there are thirteen major fault systems and a hundred active faults in Myanmar territory. They are: (1) Kaladan- Mrauk- U fault system; (2) Kabaw fault system; (3) Pyay fault; (4) Yenangyaung thrust; (5) Tangyidaung – Chauk thrust; (6) Tuyin Taung – Gwegyo thrust; (7) West Bago Yoma –Thegon fault system; (8) Shweli fault system;(9)Momeik fault system; (10) Shan Scarp –PaungLaung fault system; (11) Kyaukkyan- Papunfault system; (12) Golden Triangle fault system; and (13) Three Pagodas fault system. Among them, Sagaing fault is the most active and others seem to have a rate of displacement of 5 to 30 percent compared to Sagaing.

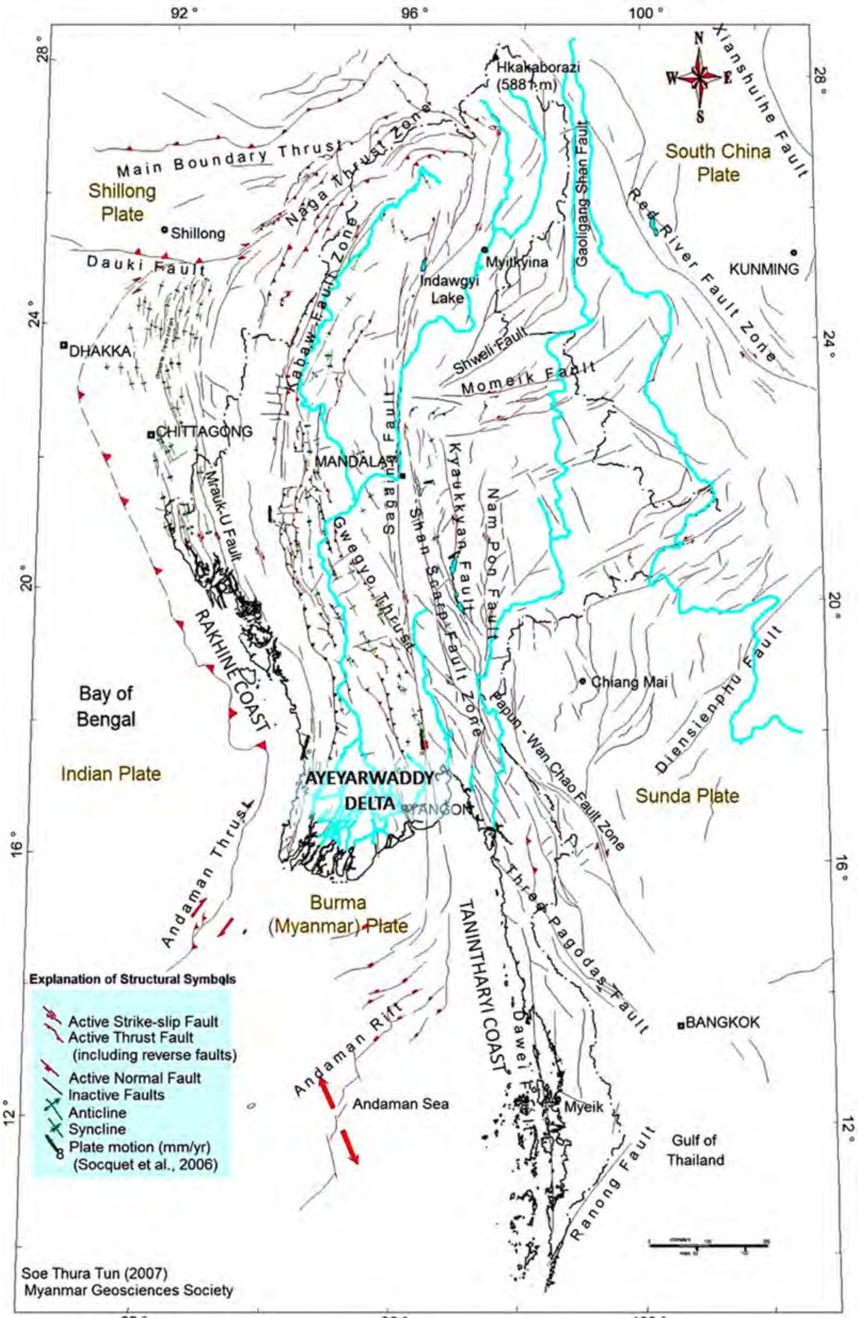
The majority of the earthquakes in Myanmar are mainly confined to three zones as follows (Hazard profile of Myanmar 2009):

i) The zone along the western fault belt of Myanmar that has mostly intermediate focus earthquakes. The earthquake frequency is much higher in the northern part.

ii) The zone along the Sagaing fault, including the offshore part with shallow focus earthquakes. The earthquake frequency is much higher in the three segments (from south to north), Bago – Taungoo, Sagaing- Tagaung, and Myitkyina- Putao.

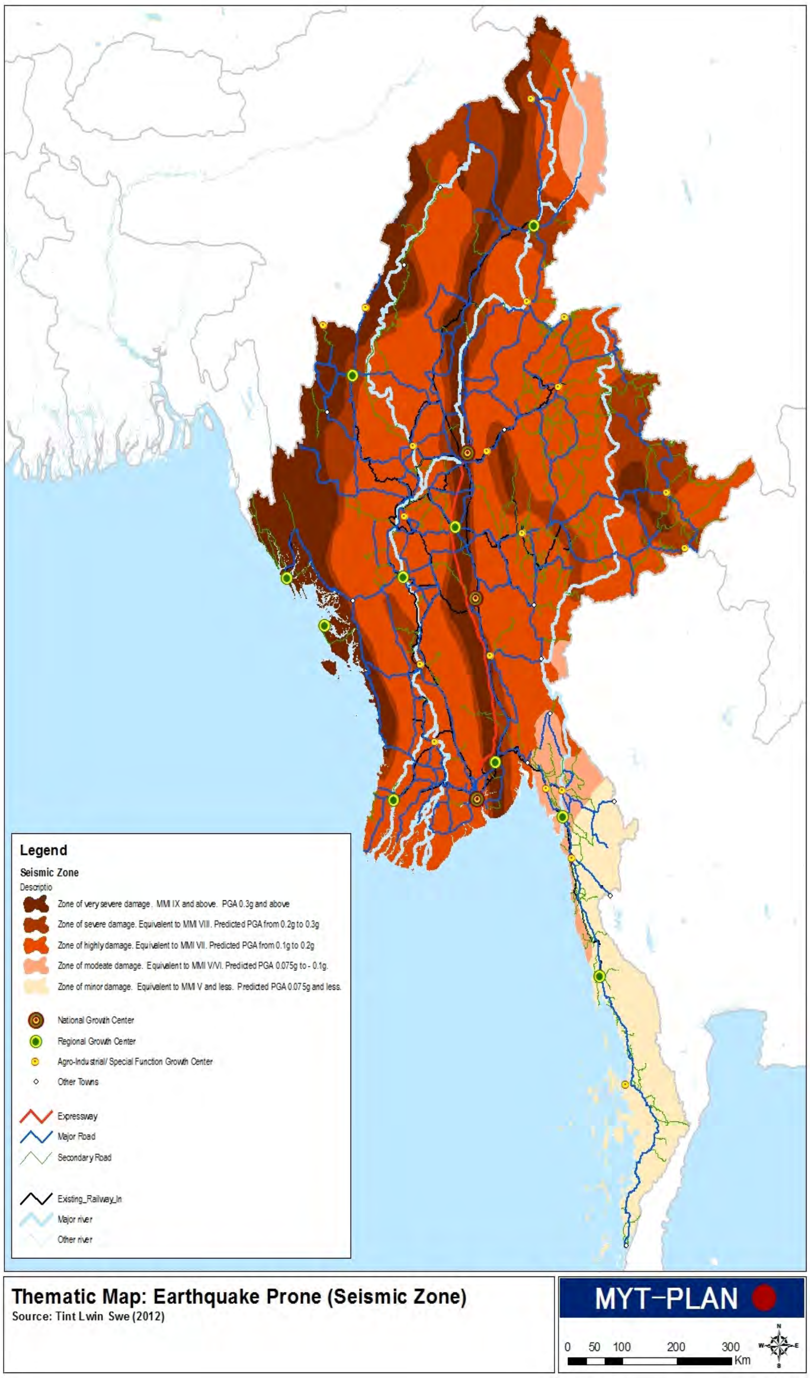
iii) The zone in the north eastern part of Myanmar which is continuous to the earthquake belt in southern Yunnan.

The following Figure 3.3.1 presents the Tectonic Map of Myanmar region (revised in 2007) showing the plates and major fault zones. It also shows active faults that run from north to south in the western mountainous area with some passing through the centre of Myanmar. And Figure 3.3.2 shows earthquake prone areas and active faults in Myanmar.



Source:
https://www.researchgate.net/publication/298513092_EARTHQUAKE_AND_TSUNAMI_HAZARD_IN_MYANMAR

Figure 3.3.1 Tectonic Map of Myanmar



Source : MYT-PLAN based on MIMU

Figure 3.3.2 Earthquake Prone Areas and Active Faults in Myanmar

3.3.2 Records of Earthquakes in Myanmar

The seismic records show that there have been at least sixteen major earthquakes with Richter magnitude (RM) ≥ 7.0 within the territory of Myanmar in the past 170 years. The frequency with respect of time may be summarized in Table 3.3.1.

Table 3.3.1 Summary of Earthquakes in Myanmar over Time

Richter Magnitude	Frequency	Time Range	Data Source
8.0	1	1839 – 2008	Historical record and NEIC
7 – 7.9		1839 – 2008	Historical record and NEIC
6 – 6.9	47	1950 – 2012	ANSS Catalogue
5 – 5.9	700	1950 – 2008	ANSS Catalogue

Source: Seismic Sources in Myanmar, a report by Myanmar Earthquake Committee, June 2011

(1) Historical Earthquakes in Myanmar

Numerous historical earthquakes have been recorded in the damage to religious buildings since the fifth century C.E. exhibiting the seismic nature of almost all the land of Myanmar. Historical earthquakes in Myanmar, well recorded in the geological literature like the works of the Geological Survey of India, and the history of Myanmar dynasty has been studied and summarized. These have been later revised and added to through their studies based on damage records of ancient stupas of the country. Some historical earthquakes of Myanmar that were recorded by the damage they had done to well-known pagodas around the country are presented in Table 3.3.2.

Table 3.3.2 Historical Earthquakes in Myanmar

No.	Date	Remarks
1	1429 AD	Some pagodas in the area damaged or collapsed
2	1469 AD	Pagodas both solid and hollow, and brick monasteries destroyed
3	Jul 24, 1485	Yadana, Kannartawya, and Simyarshinpagodas collapsed
4	1501	Pagodas and other masonry works in the area destroyed
5	1588	Many pagodas including Sandawshin pagoda inToungoo collapsed
6	1590	Ponnyashin and Htuparyon pagodas collapsed
7	Jun 8, 1619	Some pagodas in Sagaing damaged; ground surface broken, fish died and were found floating on rivers
8	1644	Damage mostly in Sagaing area
9	1660	It was said there was a quake in the area; probably not severe
10	1688	Some pagodas including Shweinhmyaw heavily damaged; ground cracked
11	Sep 15, 1696	Some pagodas, including Shwesaryan, Shweyinhmyaw, Shwezigon and Thihadaw damaged
12	Aug 8, 1704	Pagodas collapsed; water from the river gushed into the city of Inn-wa
13	1768	Local and even some pagodas in Bagan were destroyed
14	Jul 15, 1771	Earthquake hit Inn-wa, probably not severe
15	Jun 9, 1776	Shwesaryan pagoda as well as many in Inn-wa collapsed
16	Apr 26, 1830	A strong shock at Inn-wa
17	Mar 23, 1839	Major earthquake (M>7.0), Old palace and many buildings in Inn-wa demolished. At Amrapoora, pagodas at four corners of the city plus the city wall with turrets fell down; ground surface broken, Mingun pagoda severely damaged
18	Feb 6, 1843	Caused eruption of mud volcanoes on Ramree island (location – near 19.5 ºN, 95.5º E)
19	Oct 30, 1843	More violent than preceding event (location – near 19ºN, 95ºE)
20	Jan. 3, 1848	Another damaging earthquake (location – near 19ºN, 95.25ºE)
21	1858	Some damage in the area, more severe in Thayet, Pyay and Rakhine

Source: Seismic Hazard Assessment for Myanmar, a report by Myanmar Earthquake Committee (MEC) and Myanmar Geosciences Society (MGS), March 2012

Since the 18th century, at least fifteen major earthquakes including two historical ones in 1762 (northern Rankhine coast) and 1839 (Inn-wa ancient capital) occurred in the Myanmar territory. Some recent earthquakes with smaller magnitude (yet more than M = 6.5) occurred in central Myanmar such as the 1975 Bagan earthquake (M=6.5), 2003 Taungdwingyi earthquake (M=6.8) as well as in eastern Myanmar such as the 2011 Tarlay earthquake (M=6.8).

Recently in November 2012, a major earthquake with a magnitude of 6.8 hit north Myanmar. The most affected areas were Mandalay and Sagaing Regions where at least sixteen people were killed, 52 injured and over 400 houses, 65 schools and around 100 religious buildings were damaged.

A magnitude 6.8 earthquake struck Myanmar 25km west of Chauk on 24 August 2016. The estimated depth was 84.1km. Tremors from the earthquake were felt in Yangon, in the eastern cities of Patna, Guwahati, and Kolkata in India, in Bangkok in Thailand and in Dhaka, the capital of Bangladesh. According to reports, 171 temples in the nearby ancient city of Bagan were damaged and four people were reported dead.

(2) Significant Earthquakes in Myanmar

In Myanmar, considerable high magnitude earthquakes have occurred including some historical ones. Most of the events were > M=7.0 and causing severe damage and large number of casualties. Among these events, some are represented as below:

i) Inn-wa Earthquake – It produced a maximum intensity of MMI XI (Modified Mercalli Intensity Scale). This earthquake wrought fearful destruction in Ava and Amrapura. In addition to the damage to pagodas and temples, approximately 300 to 400 people were killed. Inn-wa has experienced very frequent shocks from the many earthquakes that have taken place here in the past.

ii) Pyay Earthquake - occurred in 1858, with aftershocks, and many houses and tops of Pagodas collapsed.

iii) Earthquakes in Rakhine Coastal Belt– recorded earthquakes were in 1762 in Sittway; in 1843 and 1848 in Kyaukpyu, where many buildings were damaged.

iv) Earthquakes in Upper Myanmar – recorded in 1906 in Putao, 1928 in Htawgaw – recorded damage to stone masonry buildings, 1931 in Kamaing- recorded landslides and rock falls, 1952 in Homalin.

v) Earthquakes in Sagaing- Tagaung Region – recorded in 1485 in Sagaing, 1871 in Mandalay, 1931 in Kaukse – minor cracking of buildings in Mandalay, 1946 in Tagaung, 1956 in Sagaing – several pagodas severely damaged and 40 to 50 people killed.

vi) Earthquakes in Pyinmana- Phyu Region – recorded in 1929 near Taungoo – reported bent railway tracks, bridges and culverts collapsed and loaded trucks overturned (Swa earthquake), 1930 near Khayan – in a zone trending north-south for 37 km south of Bago (on the Sagaing fault line); about 500 people in Bago and 50 people in Yangon were killed, in 1930 near Nyaunglebin – railroad tracks were twisted (Phyu Earthquake) and about 30 people killed; in 1931 in Pyinmana – three brick buildings sustained damages and got badly cracked, tremors were felt from Mandalay to the Bago District

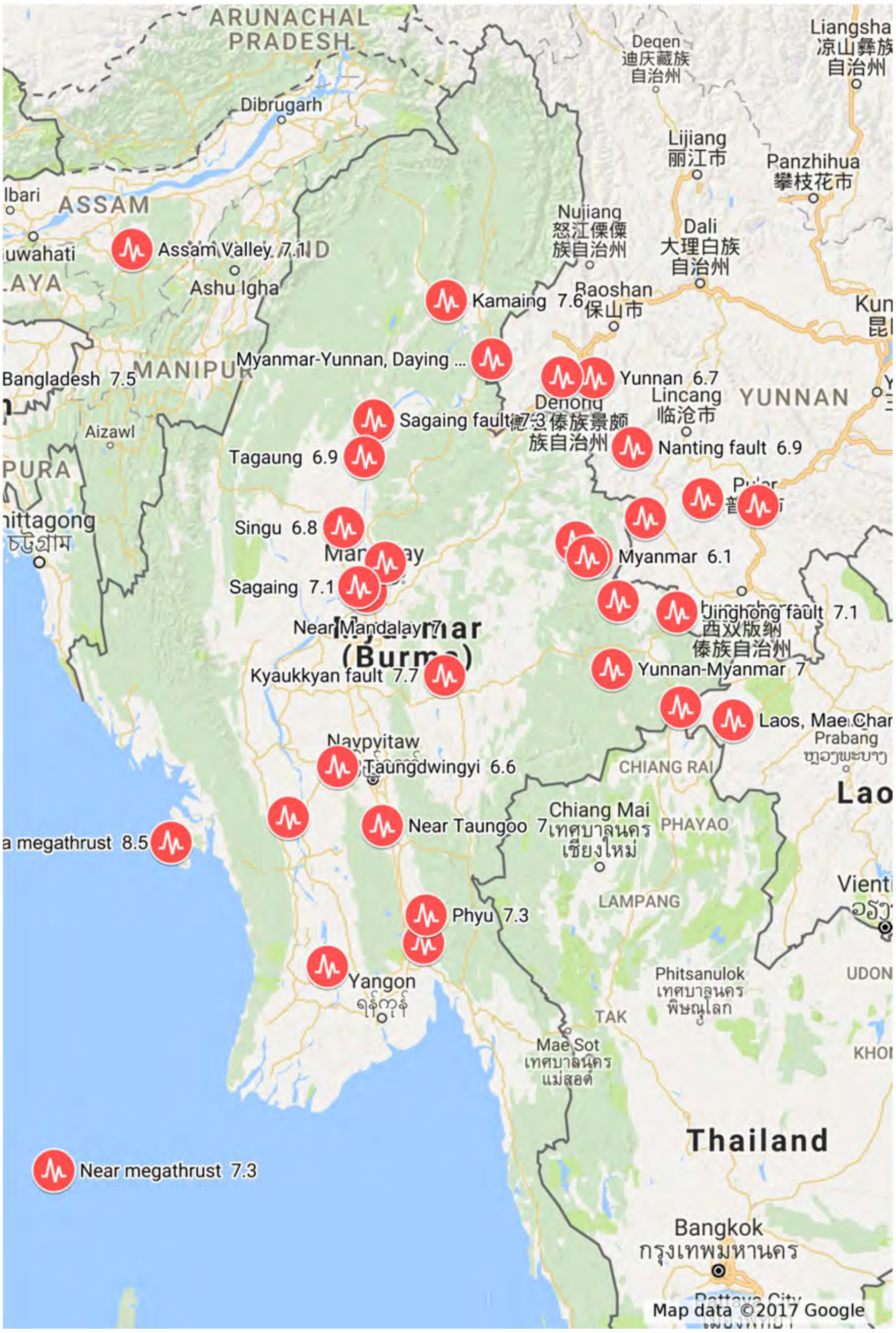
vii) Earthquakes in Central Myanmar – The three largest events were - in 1858 in Pyay; in 1975 in Bagan–several pagodas in Bagan, an ancient city, were damaged and one person was killed; in 2003 in Taungdwingyi – severe damage to rural houses and religious buildings and seven people were killed.

viii) Earthquakes in Bago- Yangon region – on Dec17 1927 in Yangon (intensity of VII based on Rossi Farrell scale) – recorded damage to the city buildings. There have been many other recorded lower intensity earthquakes in the Bago Area (southern portion of the Sagaing fault).

Earthquakes have been recorded in Yangon and the surrounding areas in the years 1568, 1661, 1664, 1668, 1927 and 1970. The 1927 and 1970 earthquakes occurred in Dedaye and there are records of the destruction of buildings. The Bago Earthquake that took place on May 5, 1930 caused extensive damage in Bago with great loss of life (500 people died). It also caused many deaths and considerable damage to property in Yangon (50 people died). A series of further shocks occurred further north on Dec 3 and 4, 1930, the severest of which wrecked the masonry buildings in the town of Phyu and caused 30 deaths.

Earthquakes in eastern such as the Myanmar–Maymyo Earthquake in 1912 – railway lines were damaged and mass landslides occurred. The railway line crosses the Kyaukkyan fault between miles 450 and 451 (between Hsum-hsai and Nawnghkio) where the foundations of earth banks were cracked and slid down to the west. Tarlay Earthquake –in 2011, an earthquake of M6.8 occurred around Tarlay town; more than 300 timber and poorly constructed brick buildings were damaged and 74 people died.

Figure 3.3.3 below shows the map of the epicentre distribution of the most significant earthquakes that occurred in and around Myanmar from the 18th Century until recently.



Source: Wang, Y, 2013, Earthquake Geology of Myanmar, 2013, Califormnia Institute of Technology

Figure 3.3.3 Historical Earthquake in Myanmar from the 18th Century until recently

3.3.3 Identification of Sources of Seismic Activities and Seismic Hazard Assessment

Two seismic reports have been referred to and studied for the YMDD1 study; (1) Seismic Sources in Myanmar produced by the Myanmar Earthquake Committee (MEC), June 2011 and (2) Seismic Hazard Assessment for Myanmar produced by MEC, Myanmar Geosciences Society (MGS) and Asian Disaster Preparedness Centre (ADPC), March 2012. The first report lists and illustrates the earthquakes in Myanmar and aims at identifying seismological sources; the second one provides a seismic hazard analysis. The relevant portions of the two reports are presented below.

In earlier times, a lack of detailed studies on historical earthquake events such as paleo seismological studies made it difficult to have a good understanding of the exact magnitudes, locations and depths of the earthquakes that took place in Myanmar. Recent studies on earthquakes in Myanmar have started since the 2003 Taungdwingyi Earthquake. Geologists from Myanmar Universities were later organized in the Myanmar Earthquake Committee (MEC).

Mitigation was recognized to be vital after Cyclone Nargisthat devastated more than 150,000 lives in Myanmar in 2008. The need for proper earthquake risk assessment was then identified.

(1) Seismically Active Systems

As for the earthquake sources, the major active faults which have been seismically very hazardous for Myanmar have been Sagaing fault, Kyaukkyan fault, Nan Pon fault, Kabaw fault, MyaunkU fault, Dawei fault, Gwegyo thrust, and some major thrusts in north – west Myanmar.

(2) Causes of Earthquakes

In the June 2011 report produced by MEC titled “Seismic Sources in Myanmar”, it was concluded that the subduction zone of the Indian Australian plate and Burma (Eurasia) along the south - western margin and the collision zone of the Indian Plate and Eurasia Plate also caused high magnitude earthquakes (even tsunami generating earthquakes) that happened in the past century. The systems of the strike slip fault in the eastern part of Myanmar also caused some of the high-magnitude disastrous earthquakes, which are now under investigation. The need for seismic hazard analysis and developing a national seismic hazard analysis map for Myanmar was brought out through the report.

3.3.4 Seismic Hazard Assessment

The hazardous effects of earthquakes include both primary and secondary effects, comprising: (1) those resulting directly from a certain level of ground shaking; (2) those on the land surface resulting from fault rupturing or deformation; and (3) those triggered or activated by a certain level of ground motion resulting in tsunami or seiche in the water bodies and landslides. The first one represents the seismic hazards that are mostly described in terms of ground motion parameters such as peak ground acceleration (PGA), peak ground velocity (PGV), peak ground displacement (PGD), and spectral acceleration (SA). Assessment of seismic hazard is the basic prerequisite for the earthquake prone areas to mitigate the hazardous effects, leading to assessment of seismic risks.

Two approaches can be utilized in seismic hazards estimation: deterministic seismic hazards analysis (DSHA); and probabilistic seismic hazards analysis (PSHA). The seismic hazard assessment brought out by MEC in its March 2012 report is the first detailed probabilistic seismic hazard analysis for Myanmar. This has been referred to for the YMDD study.

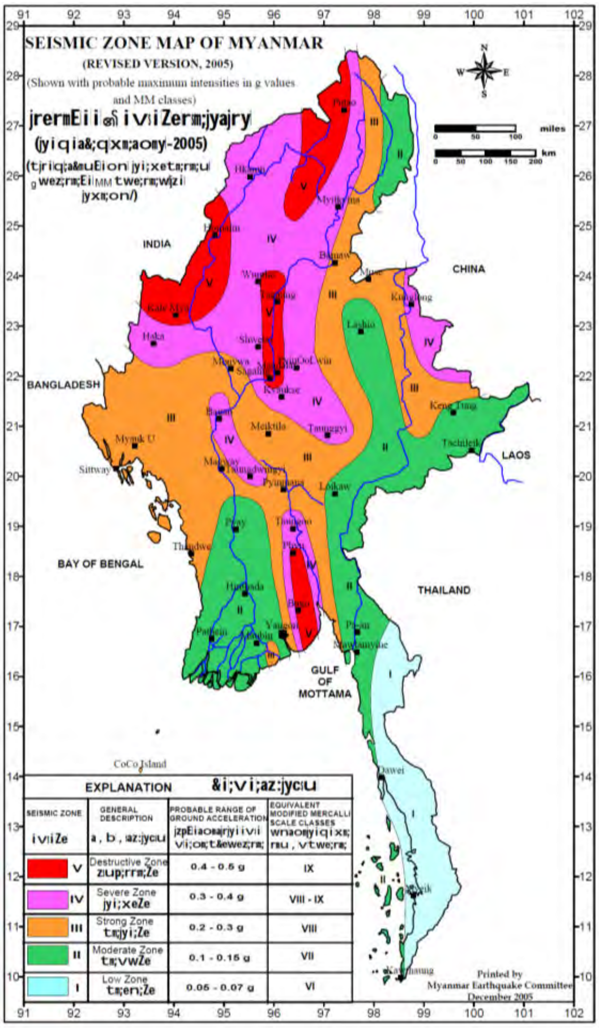
Ten PSHA maps were produced by the study for Myanmar out of which, the frequently used maps would probably be the PSHA map of 10% probability of exceedance in 50 years. These maps are generally known as the PSHA maps of 500 years recurrence interval. They have been recommended to be used by all city related planners including infrastructure planners. Seismic risk assessment is needed to understand the vulnerability of buildings and urban infrastructure in general.

With an objective of mitigating earthquake hazards in Myanmar, a seismic zone map was prepared in 1959. Earlier, first and second generation maps were being prepared. The present studies by MEC produced the third generation PSHA maps covering the whole country. A seismic zone map of Myanmar (revised in 2005) has been presented in Figure 3.3.4.

3.3.5 Impact of Earthquakes on the Project Area and Use of Collected Data in the Study

The Yangon – Mandalay railway line that is under study lies more or less running along the Sagaing fault. Most of the project area is located in the zone of severe or very severe damage where it is possible to be hit by an earthquake with MM scale of VIII to IX or stronger.

The earthquake data derived from the 'Seismic Sources in Myanmar' and 'Seismic Hazard Assessment for Myanmar' should therefore be taken into account in designing the civil works and building structures in the study.



Source: AHA CENTRE and Japan International Cooperation Agency, 2015, Country Report Myanmar, pp. 14.

Figure 3.3.4 Seismic Zone Map of Myanmar

3.4 Geotechnical Conditions

3.4.1 Scope of Objective

The soil investigation conducted during this project phase intends to define the subsurface conditions at project site as much as possible to evaluate the requirements of designing the structure.

3.4.2 Scope of Work

The scope of investigation works include three portions; field investigation work, laboratory testing and report preparation. The field investigation work includes soil boring, soil undisturbed sampling, Standard Penetration Test (SPT) and water level measuring

3.4.3 The Project Location

The project area is located at along the existing railway line from Swar Station to Mandalay Station. Total (20) boring points are assigned to conduct for geotechnical survey. The detailed location of project area is indicated in the geological map Figure 3.4.1.

3.4.4 Topography

Generally, the project area (existing of Yangon-Mandalay Railway Line) is situated at Central Lowlands of tectonic provinces of Myanmar, and between the Bago-Yoma Ranges in the West and the Shan Scarp in the East.

Sittaung River, Zawgyi River, Sin Thay Chaung and other no distinct small streams are flowing along the project area. The most occurrence of drainage system is dendritic system.

3.4.5 Regional Geologic Setting

Refer to the geological map from Geology of Burma, published by Friedrich Bender in 1983, along the project area especially existing Yangon-Mandalay Railway Line, the sediments are of Miocene, Oligocene, Eocene and small amount of Paleocene. The overburden soil layer of the project area is Quaternary Alluvial deposit (Q2), Pleistocene Older Alluvium and Gravels (Q1), and Miocene – Pliocene Irrawaddy Formation (Tm-Tp).

By boring results of soil investigation, the project area is made up of alluvial deposit of CLAY, Sandy CLAY, Clayey SAND and Silty SAND. According to the geological map, the regional geological setting of the stratigraphic succession of project area is as follow-

Description	Symbols	Age
Alluvium	Q2	Quaternary
Older Alluvium and Gravels	Q1	Pleistocene
Irrawaddy Formation	Tm-Tp	Miocene – Pliocene

3.4.6 Classification of soil layer

The soil layers are classified in accordance with their physical properties and/or their relative density. Generally nine different layers observed from BH-01 to BH-20 are described from top to bottom as follows.

1) Filled Soil
2) CLAY-I
3) Silty SAND-I
4) CLAY-II
5) Silty SAND-II
6) CLAY-III
7) Silty SAND-III
8) CLAY-IV
9) Silty SAND-IV

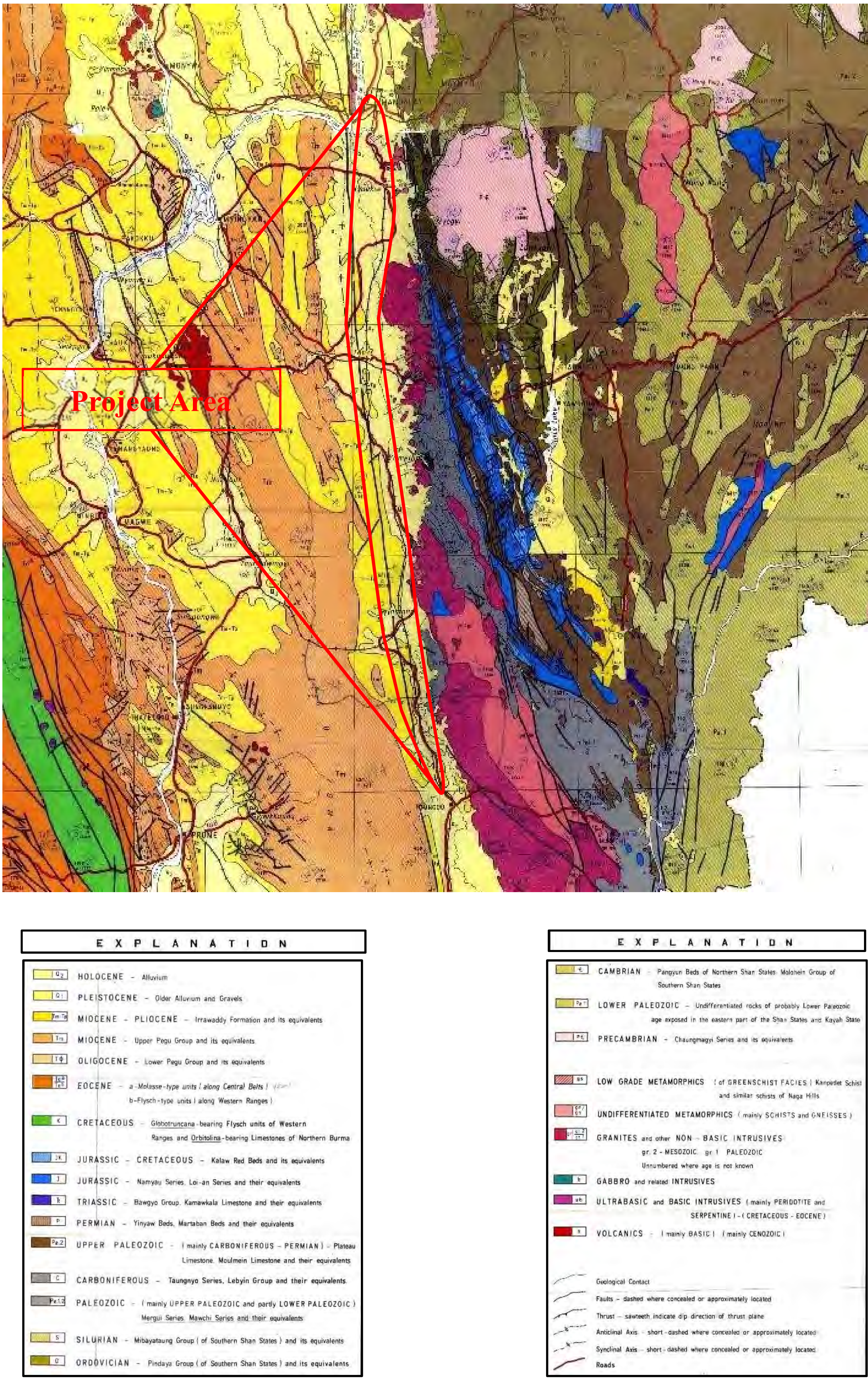


Figure 3.4.1 Geological Map of Project Area

3.4.7 FIELD INVESTIGATION

(1) Investigation works

The objective of the present investigation is to identify the general stratification of the ground and the nature of the soil. Total twenty boring points were planned to investigate by the client's requirements. The field investigation included soil boring with the performing of the test associated with Standard Penetration Test (SPT), Disturbed Soil Sampling, Undisturbed Soil Sampling, Water Level Measuring and Water Sampling. Total boring length is 712.0m and the total quantity of investigation work is listed in Table 3.4.1.

Table 3.4.1 Total Quantity of Boring Works

No.	BH. No.	Soil Drilling (m)			Standard Penetration Test (Nos)	Undisturbed Sampling (Nos)	Water Sample (Nos)
		Ø 112 mm	Ø 64 mm	Total			
1	BH-01	3.0	43.5	46.5	31	4	1
2	BH-02	3.0	33.5	36.5	24	5	1
3	BH-03	3.0	51.5	54.5	36	5	1
4	BH-04	3.0	21.0	24.0	16	2	1
5	BH-05	3.0	50.0	53.0	35	2	1
6	BH-06	3.0	26.0	29.0	19	1	1
7	BH-07	6.0	42.5	48.5	32	4	1
8	BH-08	4.0	26.5	30.5	20	2	1
9	BH-09	4.0	26.0	30.0	20	1	1
10	BH-10	4.0	23.5	27.5	18	1	1
11	BH-11	3.0	36.0	39.0	25	3	1
12	BH-12	5.0	51.0	56.0	37	1	1
13	BH-13	3.0	25.5	28.5	19	-	1
14	BH-14	5.0	24.0	29.0	19	2	1
15	BH-15	3.0	25.5	28.5	18	3	1
16	BH-16	4.0	23.0	27.0	18	3	1
17	BH-17	8.0	13.0	21.0	13	1	1
18	BH-18	4.0	31.0	35.0	23	-	1
19	BH-19	3.0	36.5	39.5	26	1	1
20	BH-20	3.0	25.5	28.5	19	2	1
Total		**77.0**	**635.0**	**712.0**	**468**	**43**	**20**

(2) Location of Boring Points

The locations of investigated points were designated by client. The plan map showing geotechnical investigated points are indicated in Figure 3.4.2. Moreover, elevation of all boring points was referred from Google earth.

(3) Standard Penetration Test (SPT)

The distribution of SPT N-value and depth in elevation for each stratum is summarized in Figure 3.4.3.

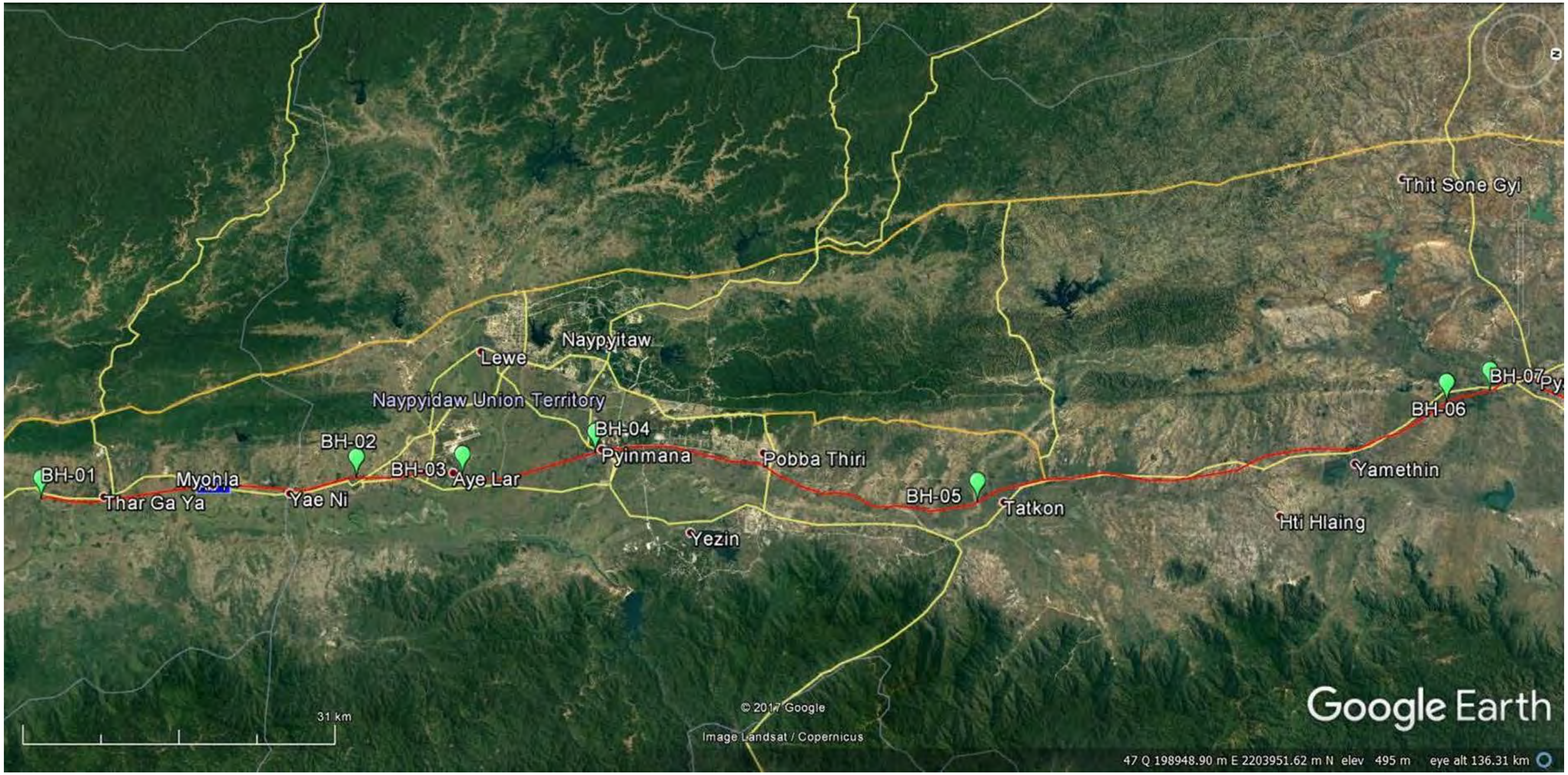
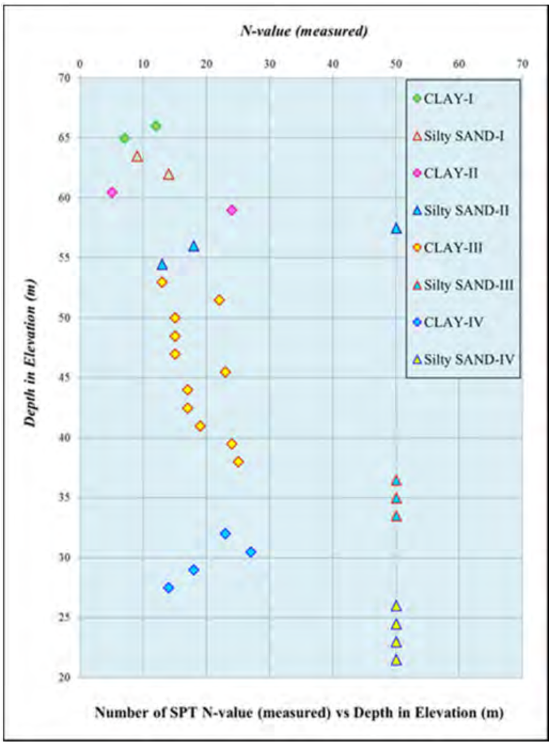
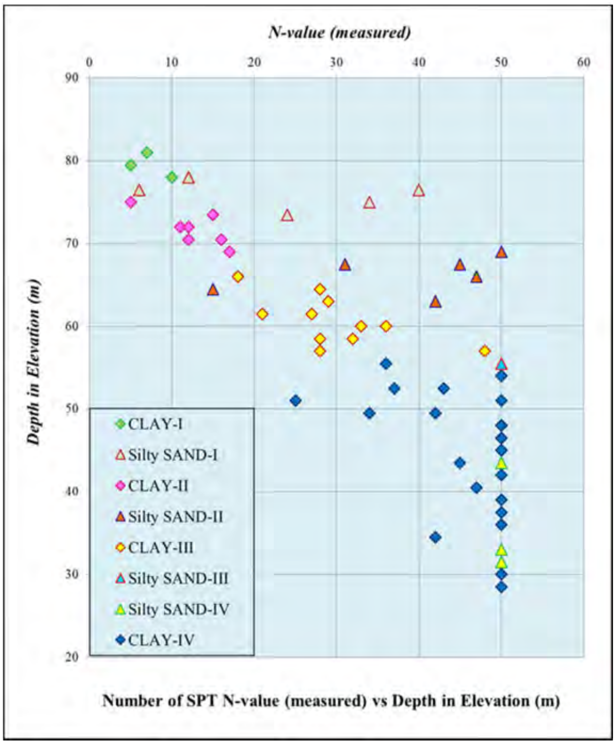


Figure 3.4.2 (a) Location of Investigated Points

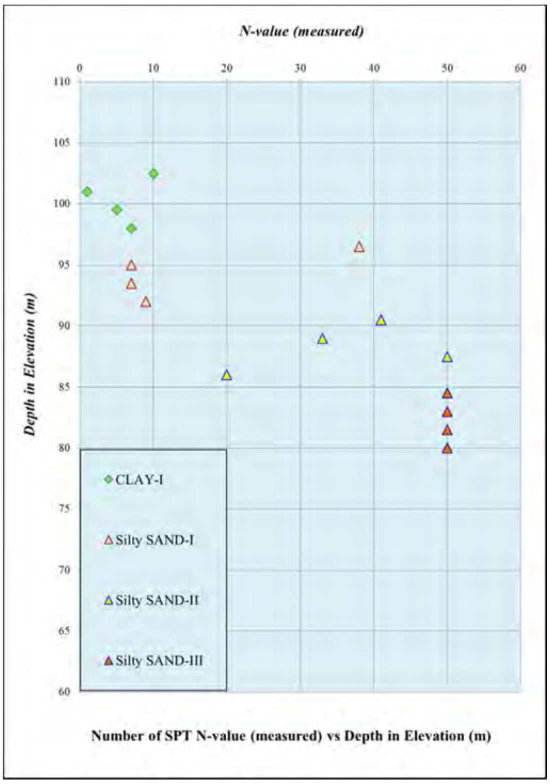
Figure 3.4.2 (b) Location of Investigated Points



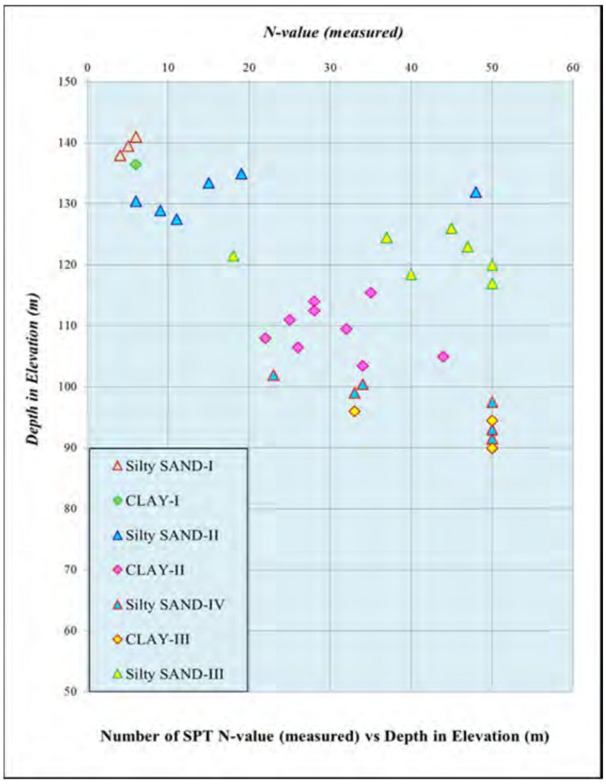
BH-01



BH-02 and BH-03

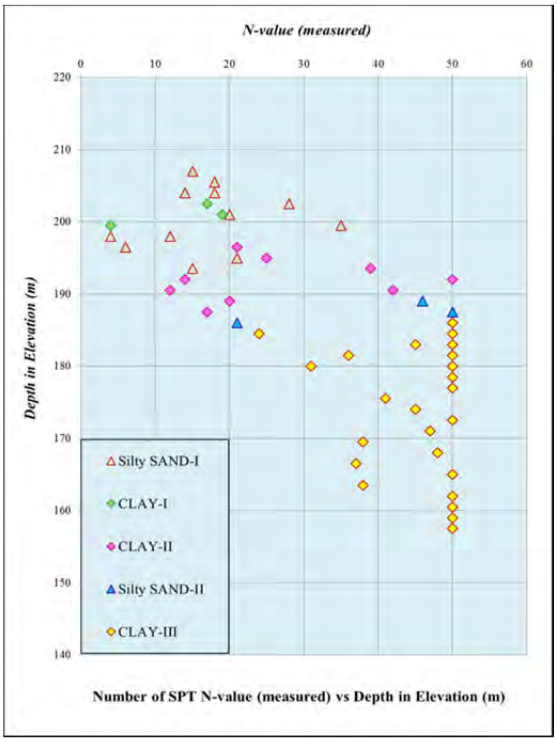


BH-04

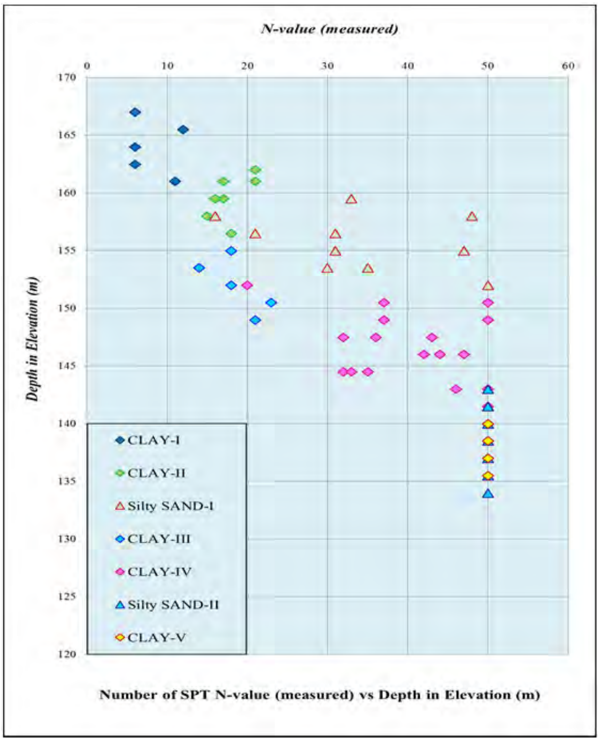


BH-05

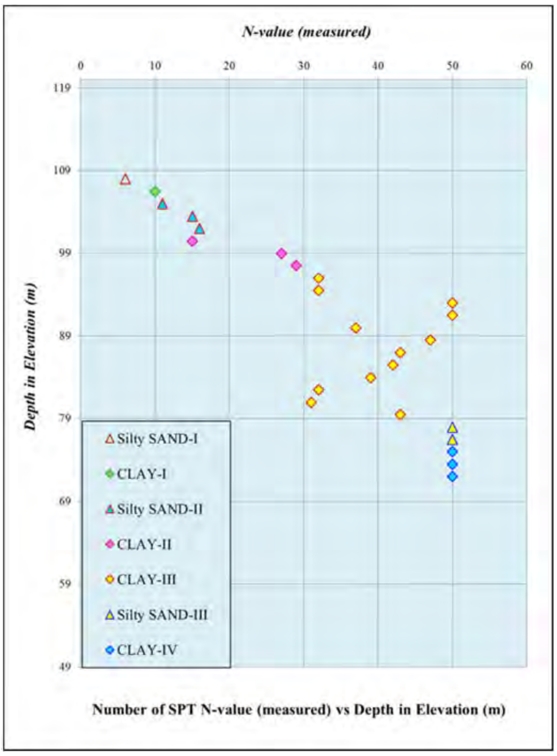
Figure 3.4.3 (a) Number of N-Value (measured) vs Depth in Elevation (m)



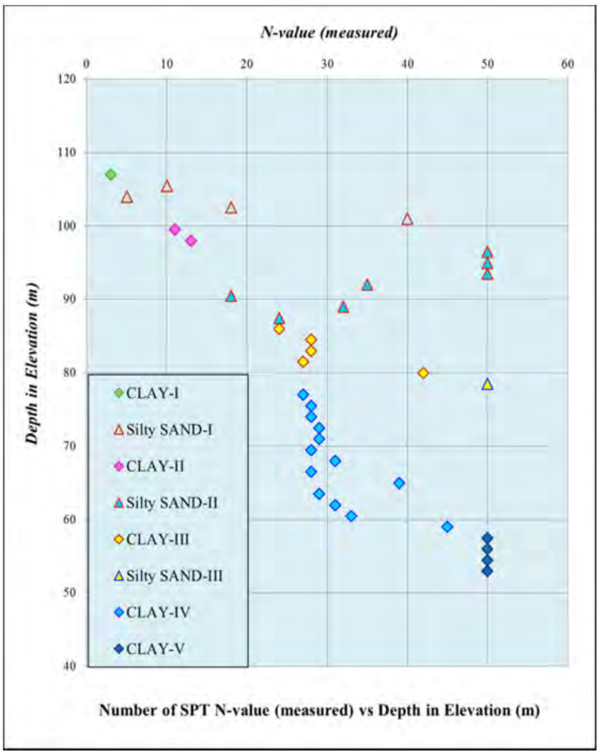
BH-06 an BH-07



BH-08 to BH-10

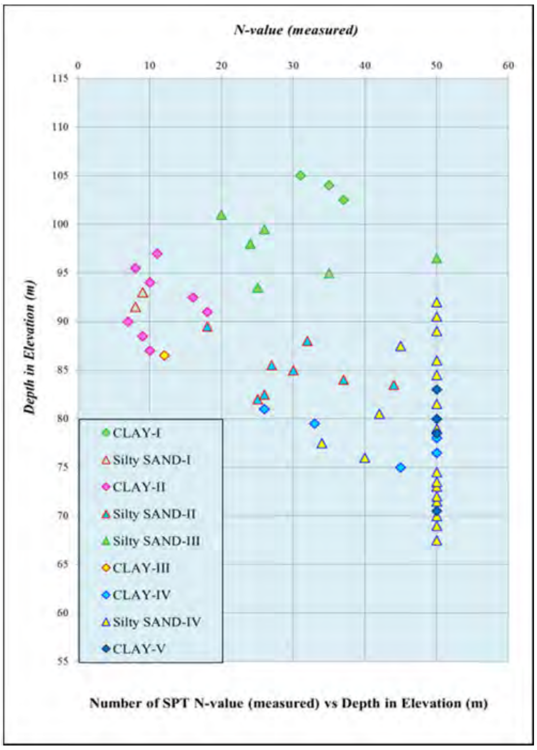


BH-11

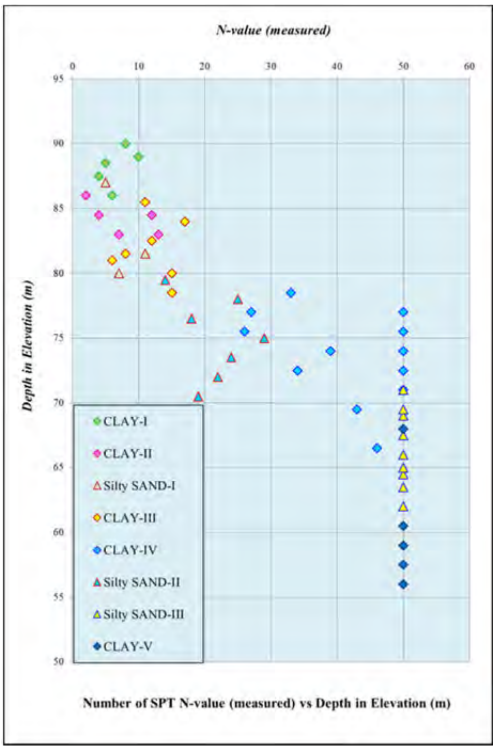


BH-12

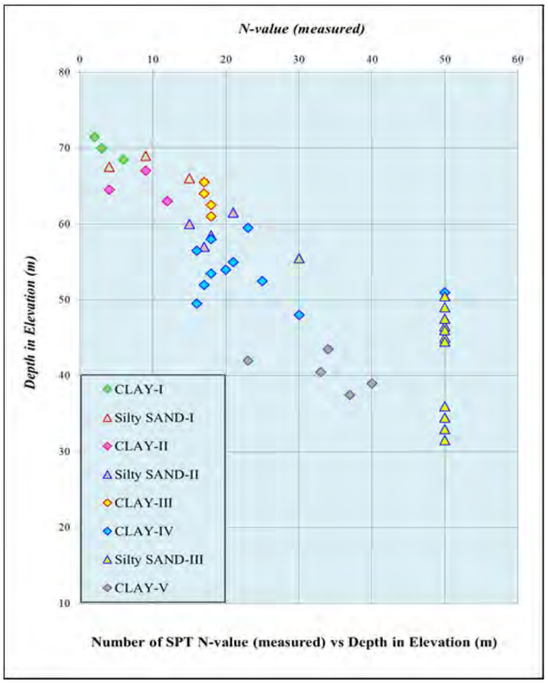
Figure 3.4.3 (b) Number of N-Value (measured) vs Depth in Elevation (m)



BH-13 to BH-15



BH-16 to BH18



BH-19 and BH- 20

Figure 3.4.3 (c) Number of N-Value (measured) vs Depth in Elevation (m)

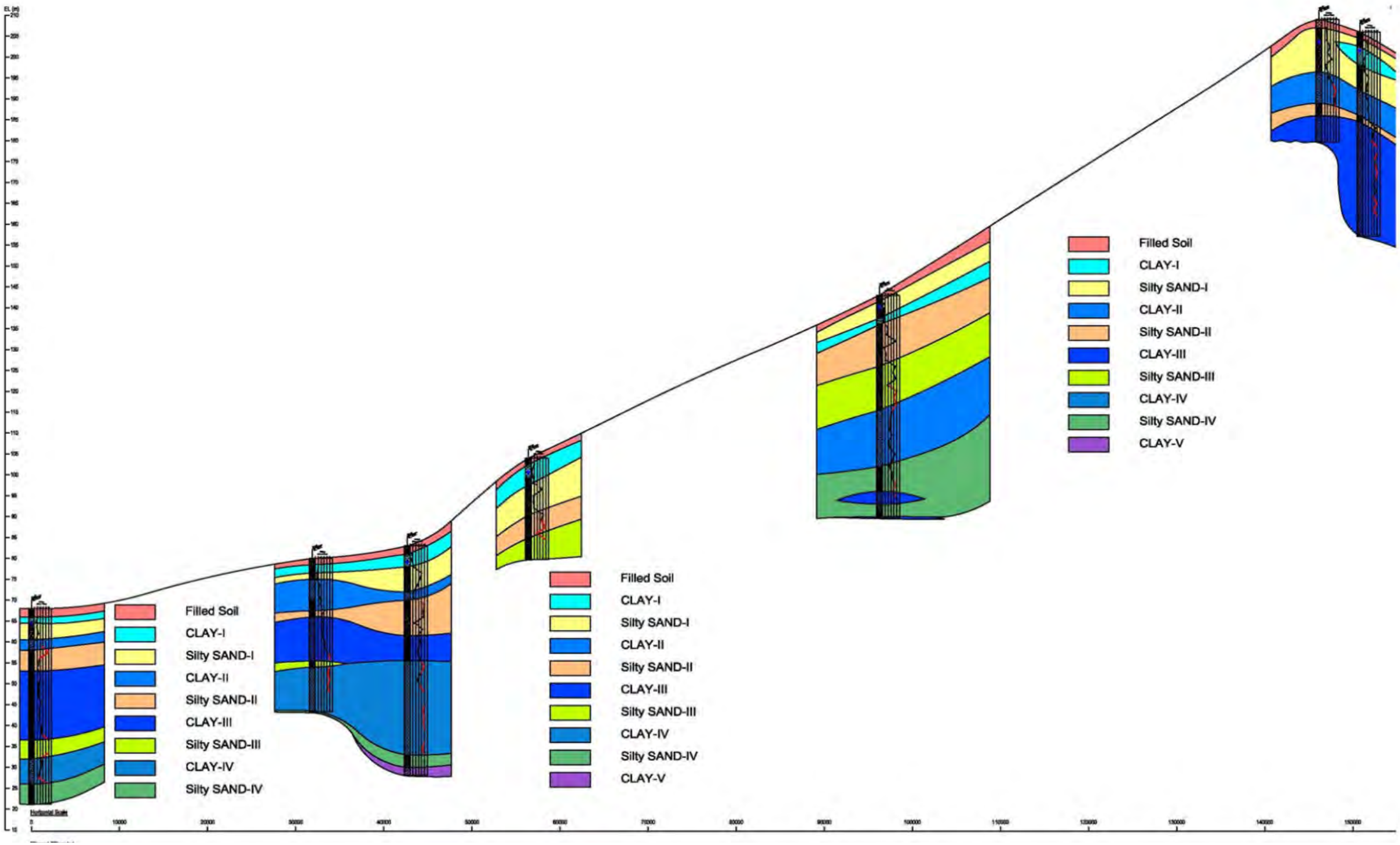


Figure 3.4.4 (a) Soil profile through the project area (A)

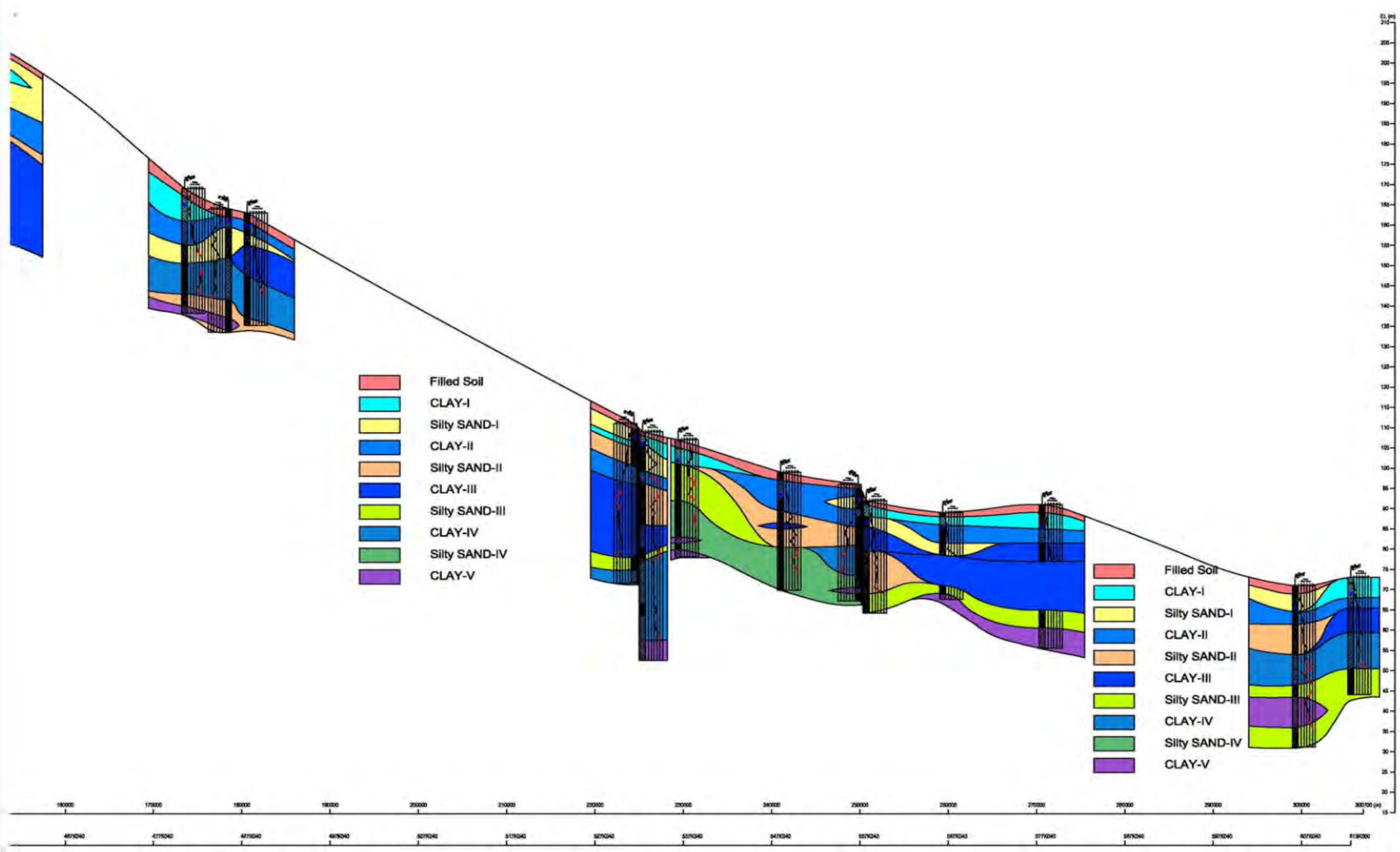


Figure 3.4.4 (b) Soil profile through the project area

3.4.8 LABORATORY TEST

There have been twenty numbers of investigation boreholes and total (468) numbers of disturbed samples and (43) numbers of undisturbed samples with Denison sampler and Piston sampler were collected in project site. Some selected numbers of disturbed samples and all undisturbed samples were sent to office laboratory and purposed to test physical and mechanical properties of soil in consulting with expert's discretion. The entire tests were carried out in accordance with ASTM Standard.

The physical properties tests include the following items.

- Natural Moisture Content Test (ASTM D 2216-05)
- Specific Gravity Test (ASTM D 854-06)
- Particle Size Analysis Test (ASTM D 422-63)
- Grain Size Distribution Test
- Hydrometer Test o Atterberg Limits Test (ASTM D 4318-05)
- Liquid Limit Test
- Plastic Limit Test

The mechanical properties tests include the following items.

- Unconfined Compression Test (ASTM D 2166-06)
- One Dimensional Consolidation Test (ASTM D 2435-04)

Total quantity of laboratory tests are described in Table 3.4.2.

Table 3.4.2 Total Quantity of Laboratory Tests

BH-No.	Physical Properties Test							Engineering Properties Test	
	Natural Moisture Content Test	Specific Gravity Test	Particle Size Analysis Test		Atterberg Limit Test		Unit Weight	Unconfined Compression Test	One Dimensional Consolidation Test
			Sieve Analysis Test	Hydrometer Analysis Test	Liquid Limit Test	Plastic Limit Test			
BH-01	25	24	25	23	18	18	4	4	4
BH-02	25	25	25	25	20	20	5	5	5
BH-03	29	29	29	29	14	14	5	5	5
BH-04	17	15	17	17	10	10	2	2	2
BH-05	24	24	24	24	12	12	1	1	1
BH-06	18	18	18	18	10	10	1	1	1
BH-07	24	24	24	24	15	15	3	3	3
BH-08	19	18	19	19	16	16	2	2	2
BH-09	18	18	18	18	12	12	1	1	1
BH-10	17	17	17	17	9	9	1	1	1
BH-11	20	20	20	20	16	16	3	3	3
BH-12	24	24	24	24	16	16	1	1	1
BH-13	18	18	18	18	7	7	-	-	-
BH-14	19	19	19	19	14	14	1	1	1
BH-15	19	19	19	17	12	12	3	3	3
BH-16	19	17	19	15	5	5	2	2	2
BH-17	15	15	15	14	5	5	1	1	1
BH-18	18	18	18	18	11	11	-	-	-
BH-19	20	16	20	18	8	8	1	1	1
BH-20	19	19	19	19	14	14	2	2	2
Total	407	397	407	396	244	244	39	39	39

3.4.9 Liquefaction Potential at Site

(1) General

Liquefaction is one of the catastrophic of earthquake related hazards. According to the investigation results, engineering properties of some soil layers have been identified as potential of liquefaction. According to the theoretical research, the quicksand is high potential to liquefaction. The term quicksand (after Terzaghi, 1925) is referred to three conditions. First the sand or silt concerned must be saturated and loosely packed. Second, on disturbance of constituents grains become more closely packed, which leads to an increase in pore water pressure, reducing the forces acting between the grains. This brings about a reduction in strength. The third condition requires that pore water cannot escape readily. This is fulfilled if the sand or silt has a low permeability and/or the seepage path is long. As the above reasons, poorly graded sand of fine to medium grained and silty sand of saturated condition have high potential to liquefaction. Liquefaction of potential quicksand may also be brought about by sudden shocks caused by the action of heavy machinery and blasting.

According to the investigation results for a lot of earthquake experience in the world, it is said that the liquefaction can occur easily under the following condition.

- Lower fine content of saturated soil (Fine content is meant the size less than 0.07 mm)
- Lower SPT blow count (N) of saturated soil (SPT N-value < 20 blows per 30 cm)
- Shallow groundwater table
- Bigger maximum peak acceleration

(2) Liquefaction Analysis Procedure

In this analysis, magnitude of earthquake and peak acceleration at ground surface is assumed as 0.3g to 0.4g, and MM Class is 7.5 in this area. Moreover, the detailed probable ground peak acceleration of each borehole are shown in Table 3.4.3. And, water table at site is actual water table from field investigation results.

Table 3.4.3 The probable ground peak acceleration of each borehole

BH No.	Ground Peak Acceleration (g)	BH No.	Ground Peak Acceleration (g)
BH-01	0.40	BH-11	0.30
BH-02	0.30	BH-12	0.40
BH-03	0.30	BH-13	0.40
BH-04	0.30	BH-14	0.40
BH-05	0.30	BH-15	0.40
BH-06	0.30	BH-16	0.40
BH-07	0.30	BH-17	0.40
BH-08	0.30	BH-18	0.40
BH-09	0.30	BH-19	0.40
BH-10	0.30	BH-20	0.40

Liquefaction analysis is performed by following two methods:

- "Design Standard and Explanation of Railway Structure" Railway Technical Research Institute, 2012.9
- "Highway Bridge Design Guideline, Anti-earthquake design Chapter" Japan Road Association, 2012.3

(3) Potential of Liquefaction (PL)

P_L was originally developed in Japan to estimate the potential of liquefaction to cause foundation damage at a site (Iwasaki, 1978). P_L assumes that the severity of liquefaction is proportional to the:

- Thickness of the liquefied layer;
- Proximity of the liquefied layer to the surface; and
- Amount by which the factor of liquefaction (FL)

The potential of liquefaction can be calculated by following formula;

$$P_L = \int_0^{20} (1 - F_L)(10 - 0.5z)dz$$

Where,

P_L = potential of liquefaction

F_L = factor of liquefaction

z = Depth in meters

Potential of liquefaction condition is shown in Table 3.4.4

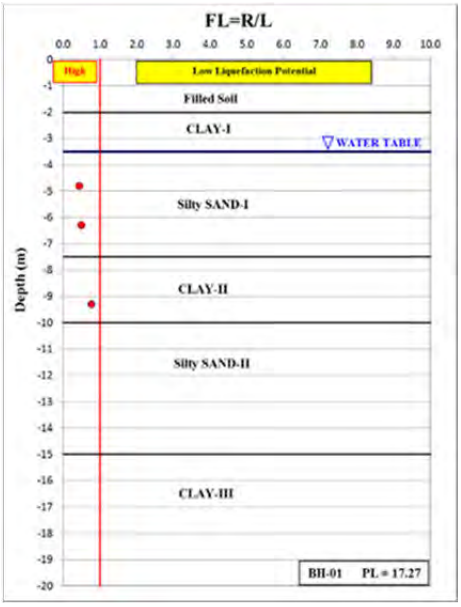
Table 3.4.4 Potential of Liquefaction condition

$15 < P_L$	High Possibility of Liquefaction
$5 < P_L \leq 15$	Possibility of Liquefaction
$0 < P_L \leq 5$	Low Possibility of Liquefaction

(4) Liquefaction Analysis Results

Summary of liquefaction analysis results are shown in Figure 3.4.5 and Figure 3.4.6. The result analyzed by “Railway structure design” and “Highway Road Bridge Design” is shown respectively. Result of liquefaction result is shown in Figure 3.4.7.

(5) Analysis Results by Railway structure design



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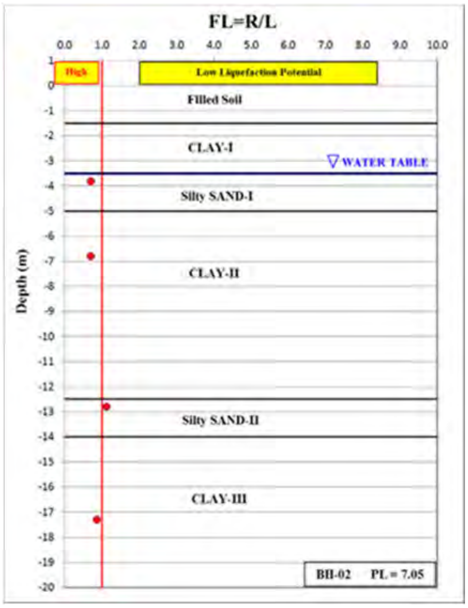

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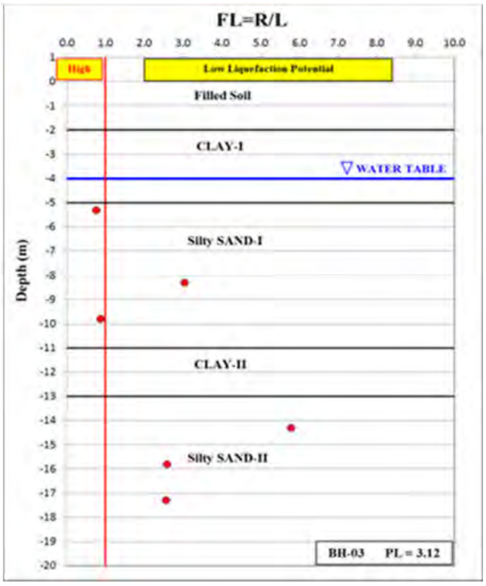

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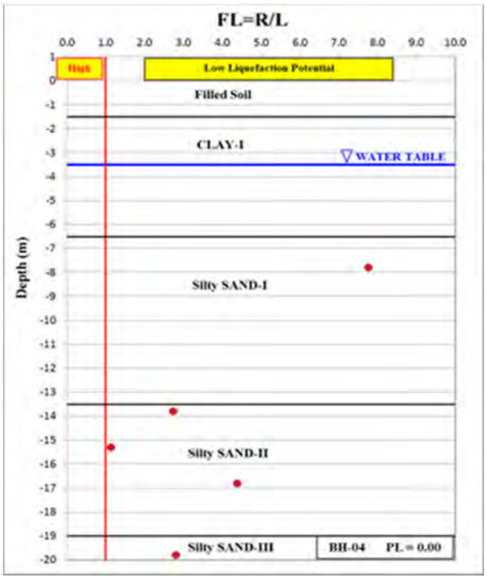
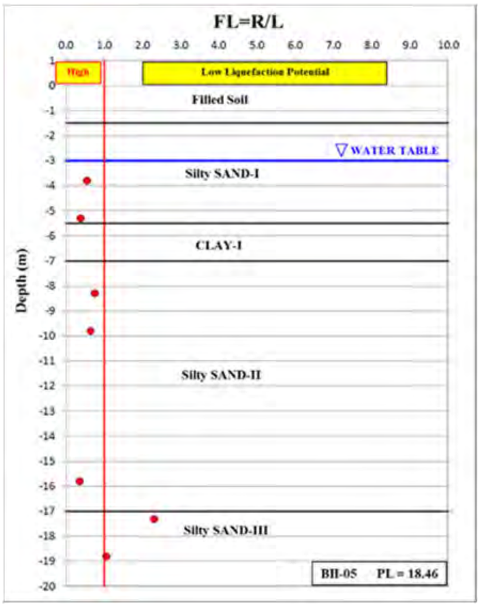


BH-04

Figure 3.4.5 (a) Distribution of liquefaction potential vs depth in elevation (m)



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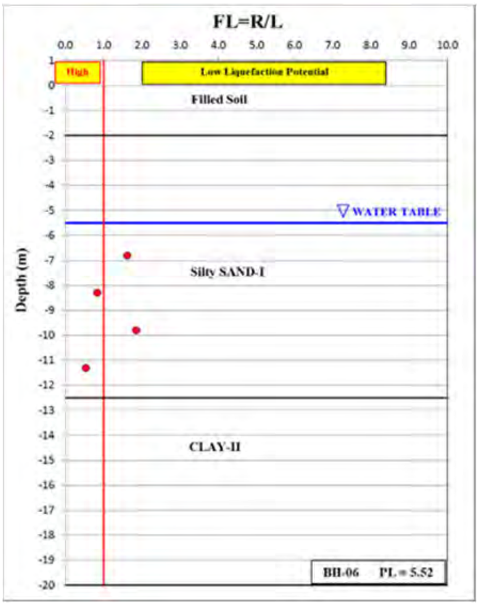

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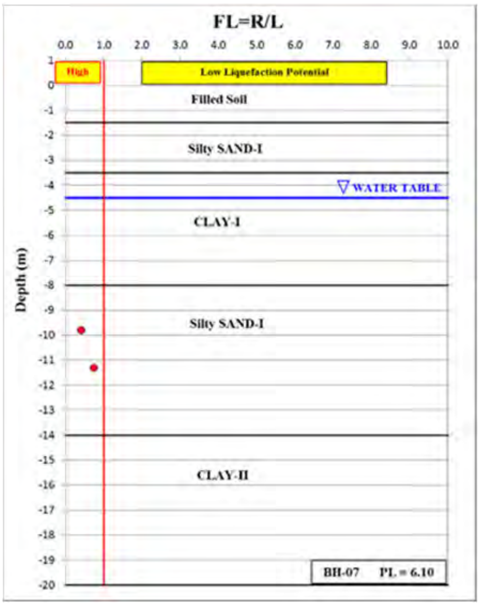

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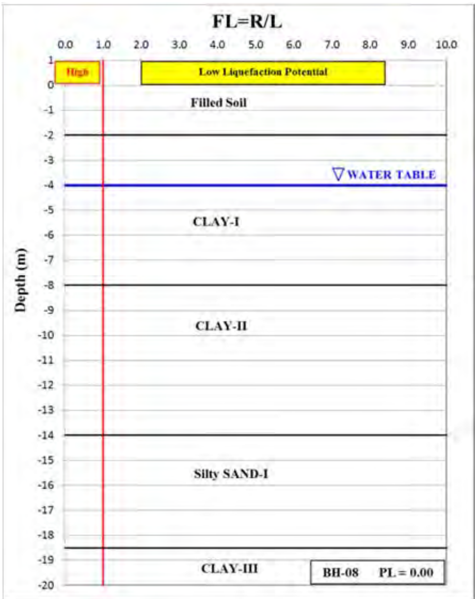
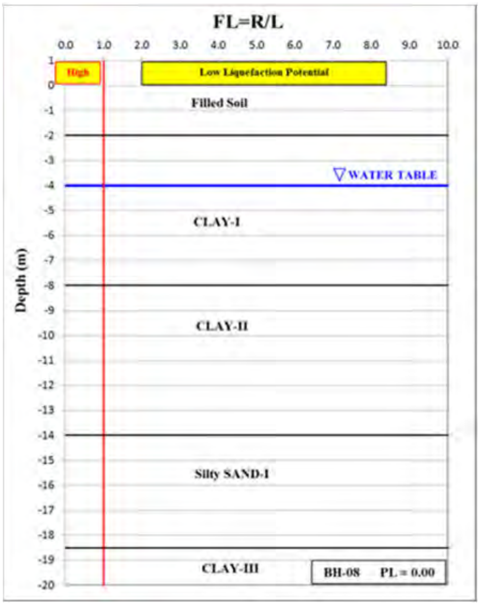


BH-08

Figure 3.4.5 (b) Distribution of liquefaction potential vs depth in elevation (m)



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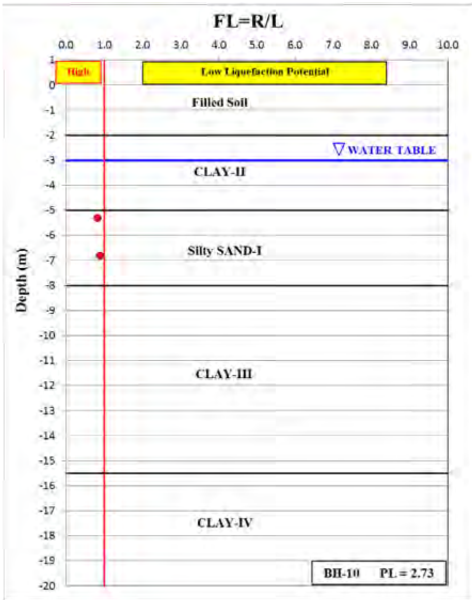

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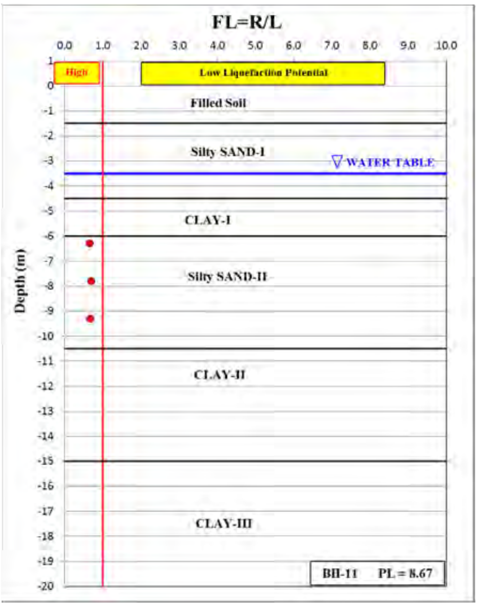

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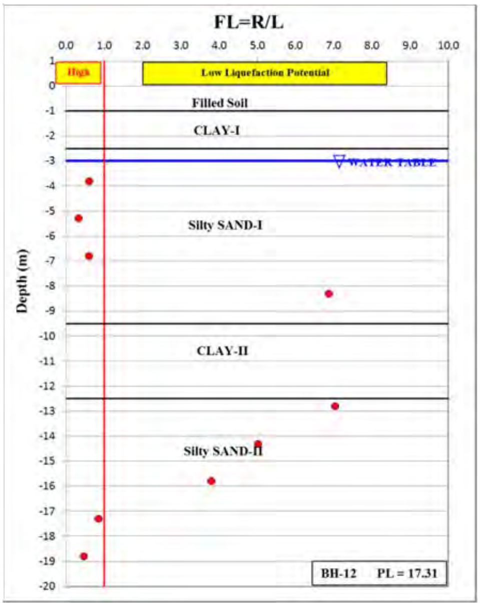
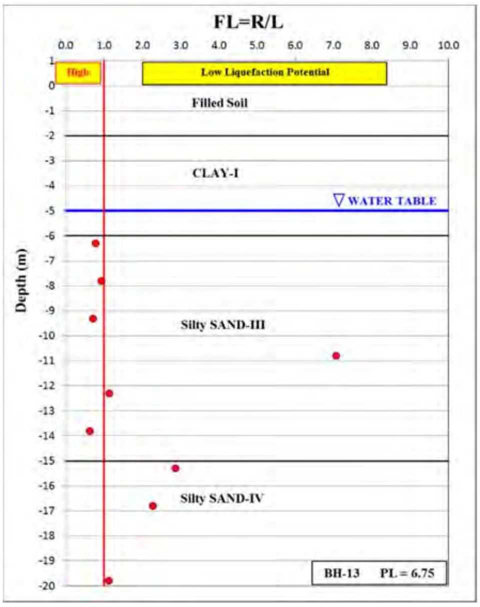


BH-12

Figure 3.4.5 (c) Distribution of liquefaction potential vs depth in elevation (m)



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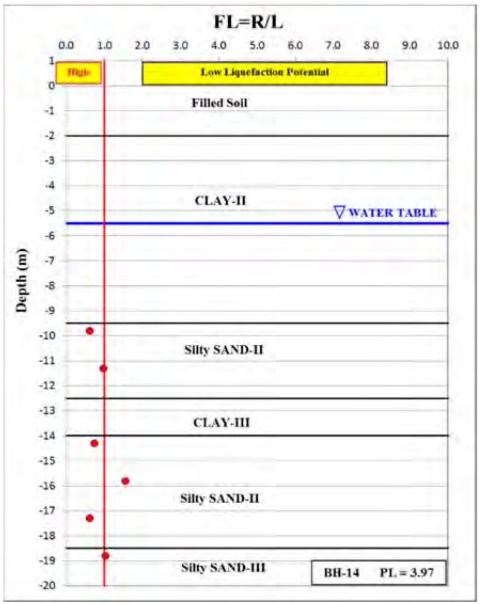

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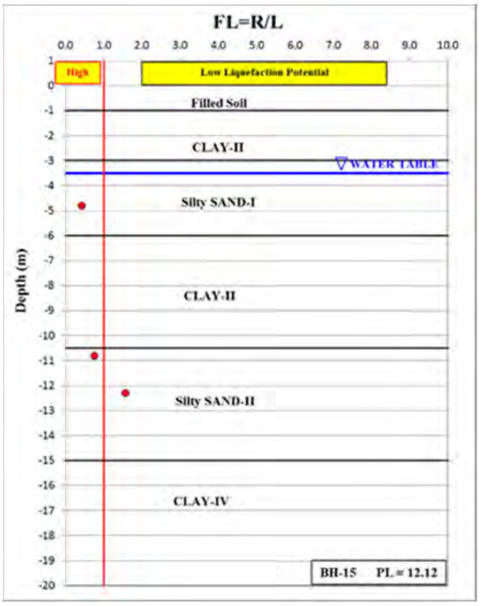

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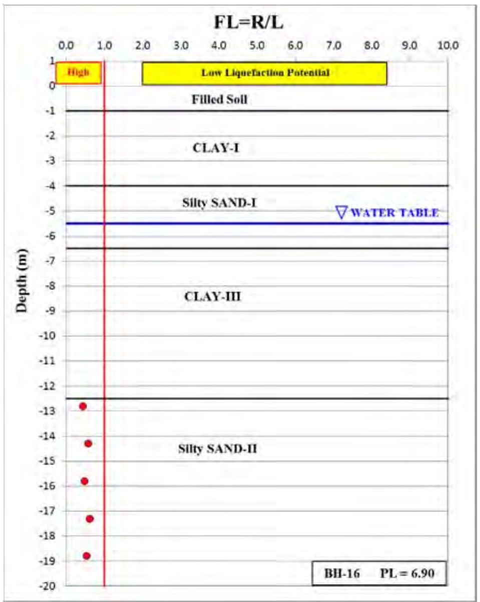
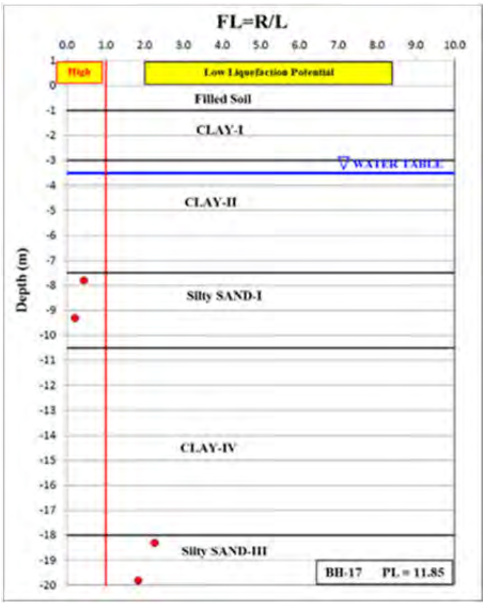


BH-16

Figure 3.4.5 (d) Distribution of liquefaction potential vs depth in elevation (m)



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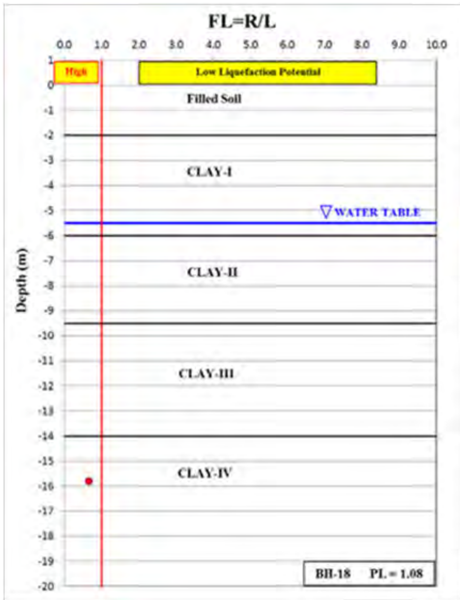

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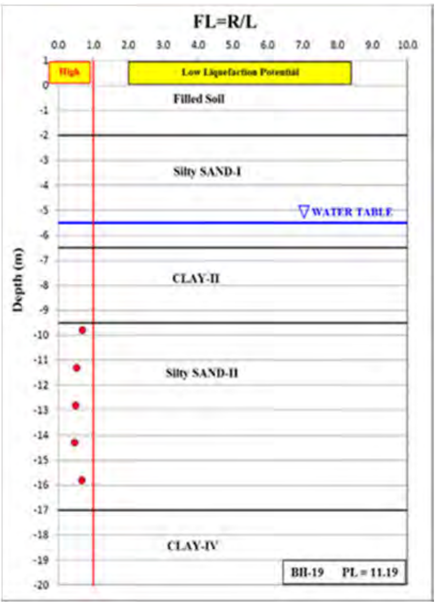

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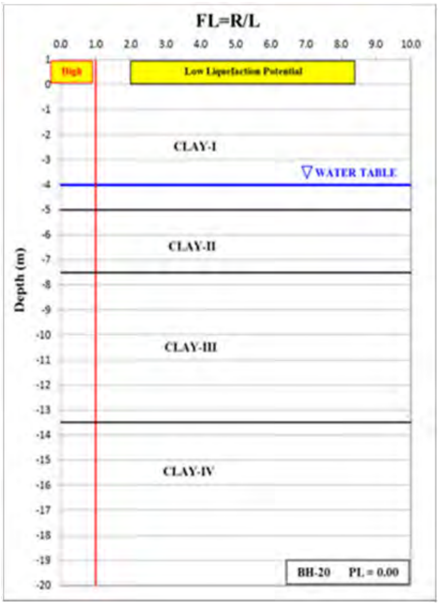
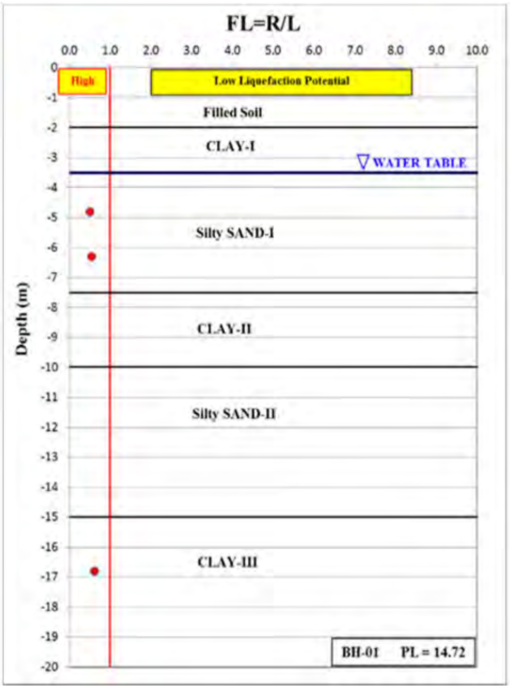


BH-17

Figure 3.4.5 (e) Distribution of liquefaction potential vs depth in elevation (m)

(6) Analysis Results by Highway Bridge Design Guideline



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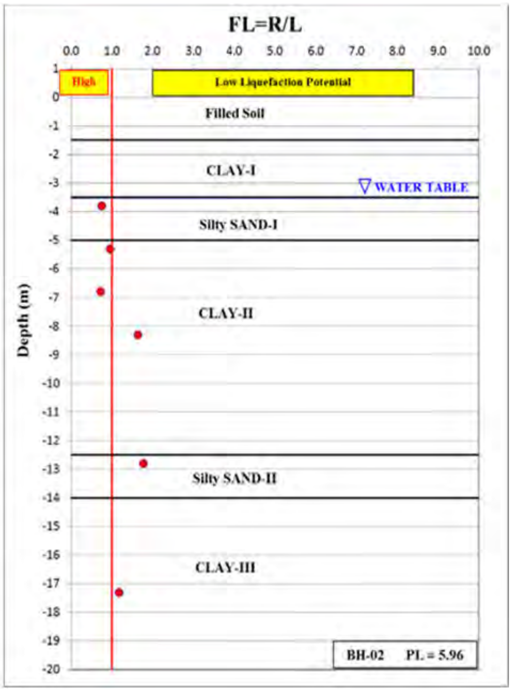

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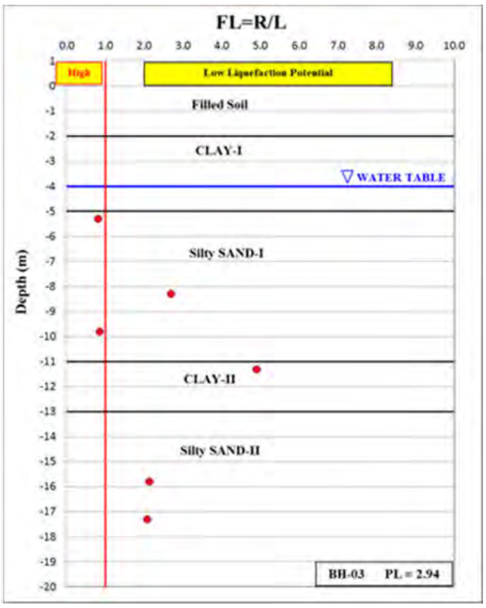

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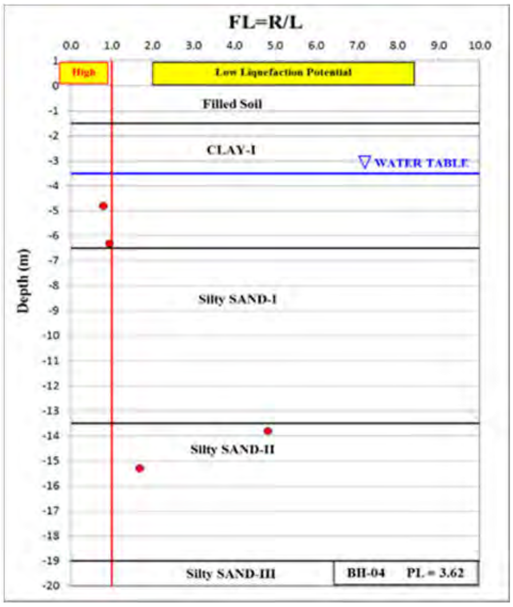
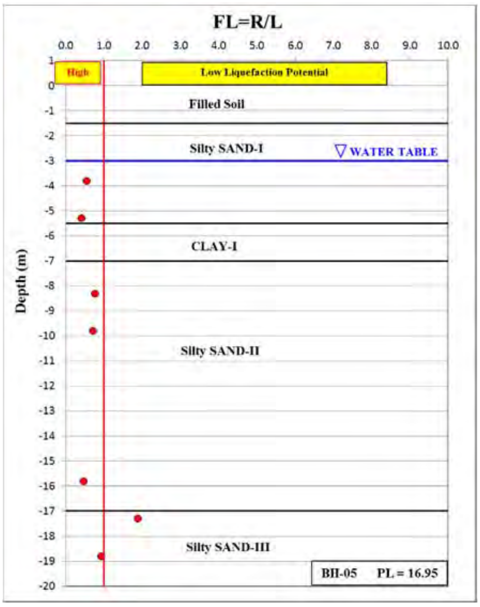


BH-04

Figure 3.4.6 (a) Distribution of liquefaction potential vs depth in elevation (m)



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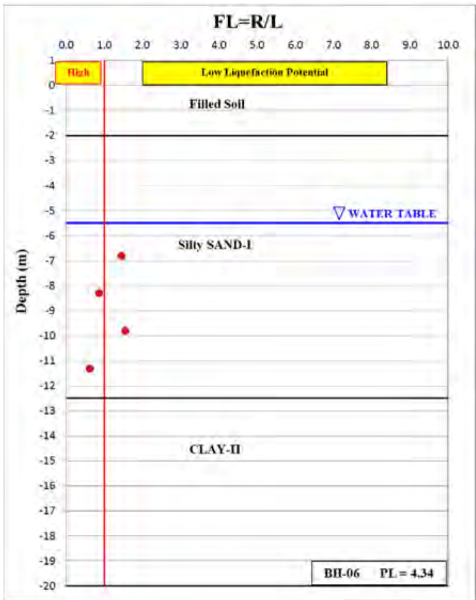

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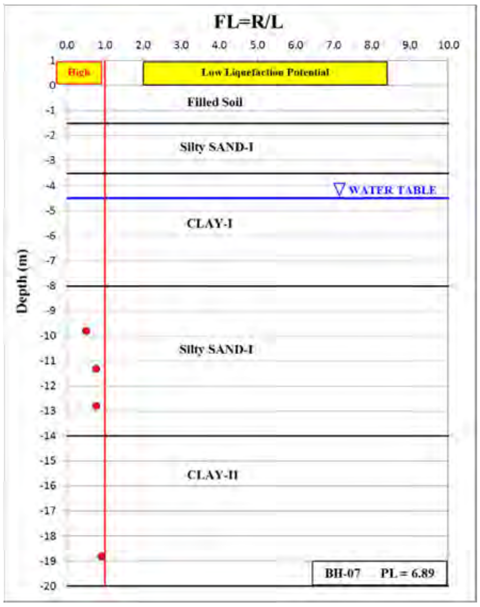

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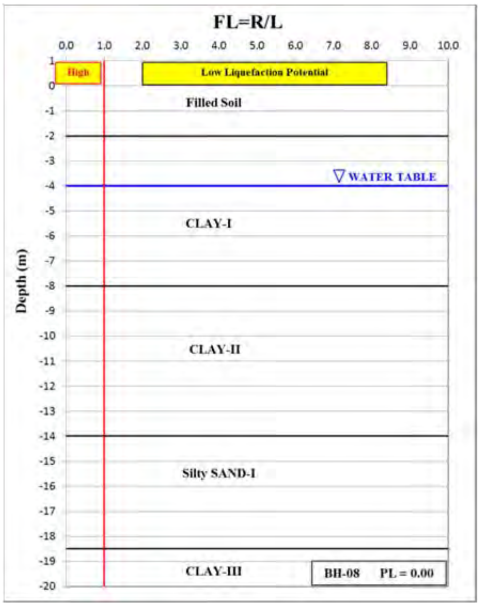
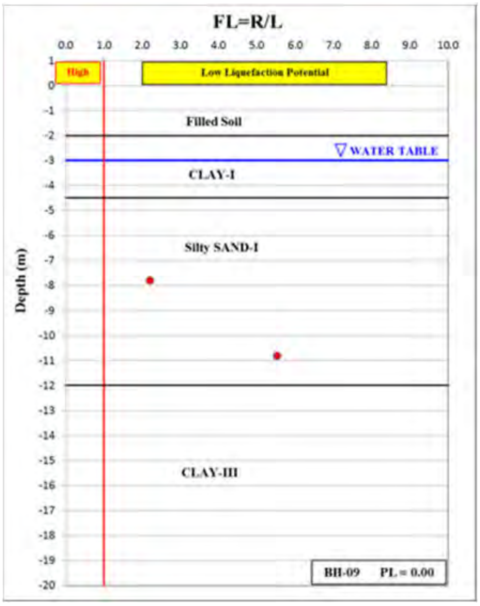


BH-08

Figure 3.4.6 (b) Distribution of liquefaction potential vs depth in elevation (m)



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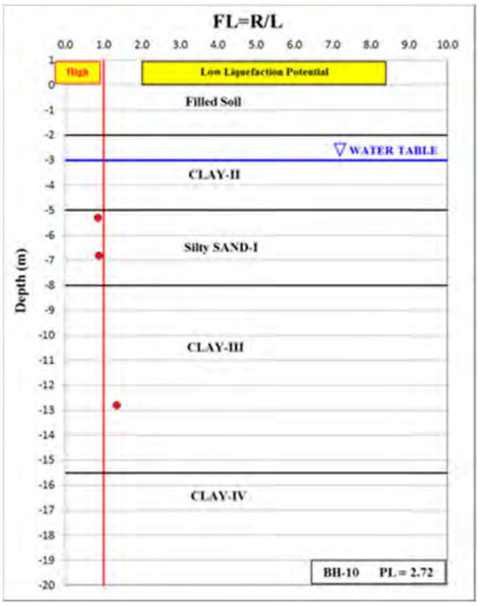

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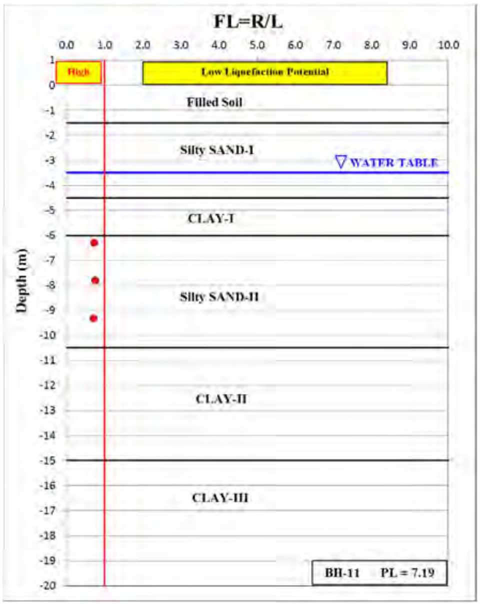

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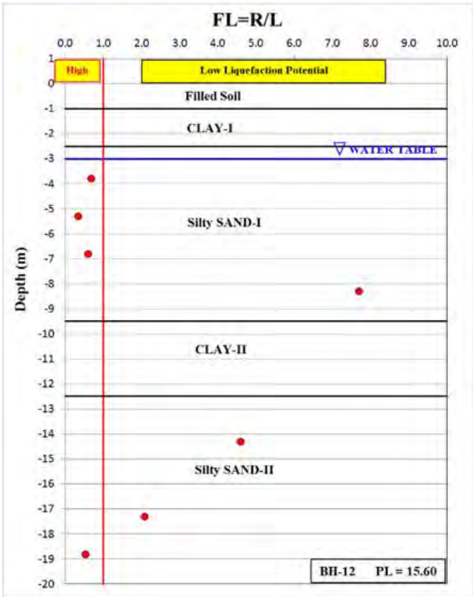
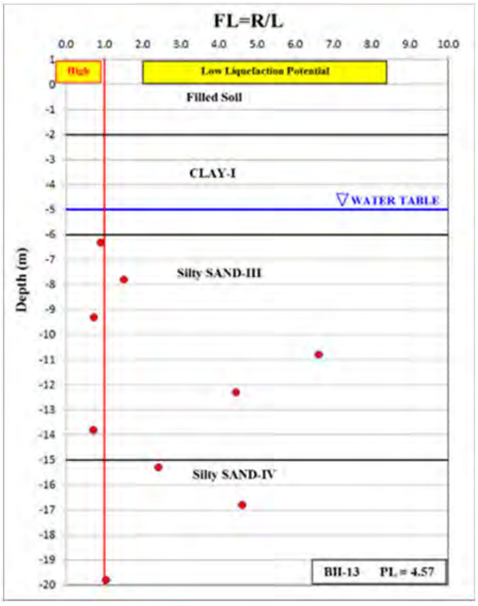


BH-12

Figure 3.4.6 (c) Distribution of liquefaction potential vs depth in elevation (m)



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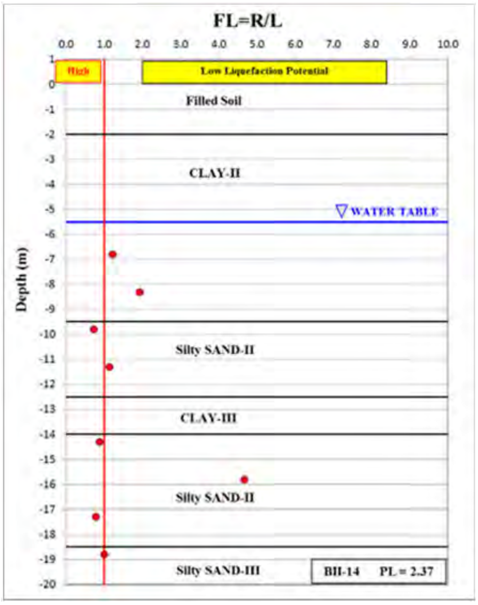

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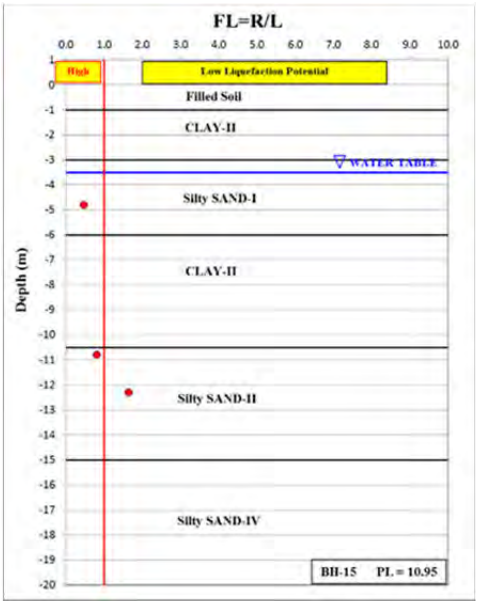
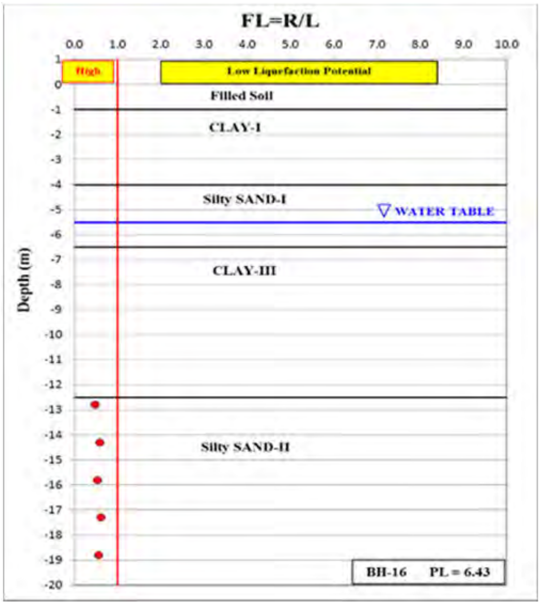


BH-15



BH-16

Figure 3.4.6 (d) Distribution of liquefaction potential vs depth in elevation (m)

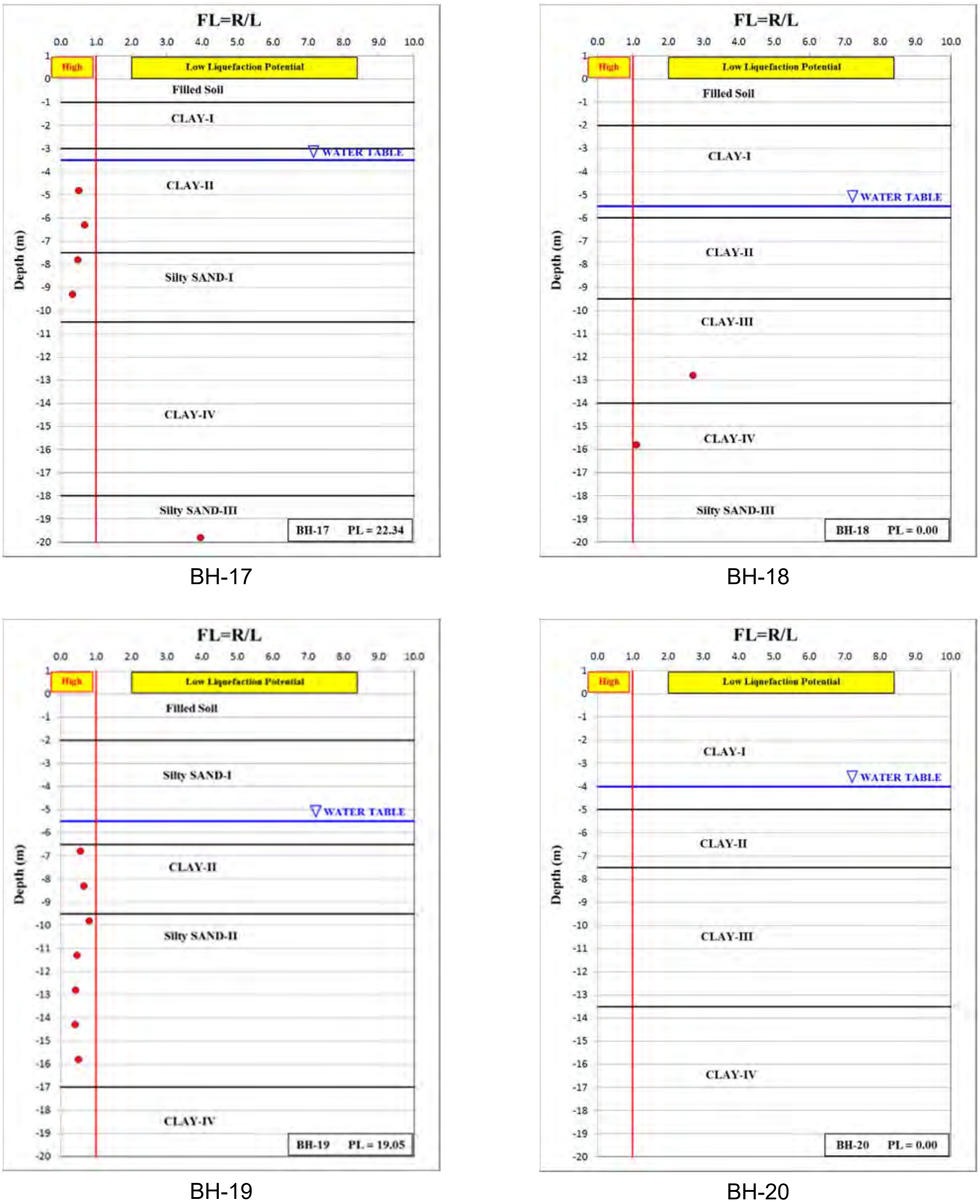


Figure 3.4.6 (e) Distribution of liquefaction potential vs depth in elevation (m)

(7) Liquefaction Index

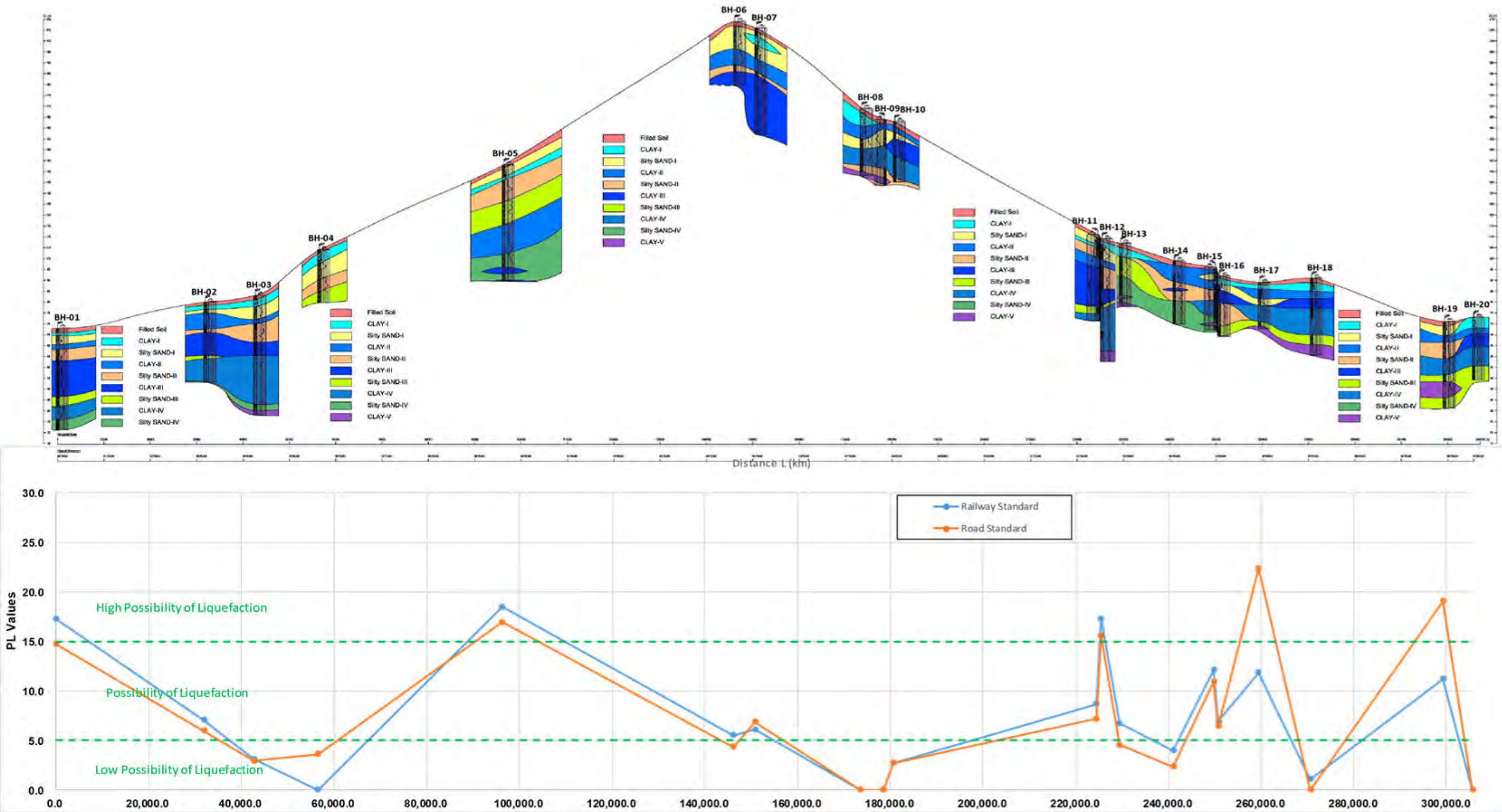


Figure 3.4.7 Result of liquefaction index

3.4.10 The Necessity of Geotechnical Survey at Detail Design Stage

In this survey, boring test are conducted in twenty bridges.Geeotechnical survey which have to be conducted at detail design stage are listed in Table 3.4.5.

Table 3.4.5 he Necessity of Geotechnical Survey at Detail Design Stage

Structure		Purpose of survey	Survey Method	Survey locaton and depth
Railway Bridges	PC girder bridges	• Structure design • Fondation design	• Boring • Labaratory test	Location: Planned replacement bridges Depth: To confirm bearing soil layer
	Box culverts	Ditto	Ditto	Location: Planned replacement bridges Depth: 20m
	Hume Pipe (Spam length L > 3m)	• Fondation design • Judgment of liquefaction	Ditto	Ditto
	Hume Pipe (Spam length L ≤ 3m)	Ditto	Ditto	Refer other near boring result, if there are no data, additional boring will be conducted. Deoth: 20m
Foot Over Bridge	Myntge Depo	• Structure design • Fondation design	Ditto	Location: Planned a foot over bridge. Depth: To confirm bearing soil layer
New Stations (7 stations)		Ditto	Ditto	Location: Planned new stations. Depth: To confirm bearing soil layer
Signal House		Ditto	Swedish Sounding test	Location: Planned new signak houses. Depth: 10m
Collapsed embankment points of guideway		• Slope stability study • Study of countermeasure s method	• Boring • Labaratory test	Locaton: Collapsed embankment points Depth: 20m
Planned horizontal alignment improvement locations		• Confirmation of Bearing capacity of roadbed	Ditto	Location: Horizontal alignment improvement locations. Refer other near boring result, if there are no data, additional boring will be conducted. Deoth: 20m

Source: JICA Study Team

Chapter 4 Railway System Parameters and Outline of Design Conditions

4.1 General

The purpose of rehabilitation and modernization for the existing railway facilities from Tangoo station to Mandalay are,

(1) Increasing passenger and freight transport capacity between Yangon-Mandalay to cope with increase traffic demand;

(2) Increasing the train operation speed;

(3) Reducing travel time;

(4) Increasing safety, reliability and punctuality of train operation and;

(5) Enhancing the national economic growth such as industries, trade, and commercial etc

The Railway Improvement Plan is as shown in table below.

Table 4.1.1 Railway Improvement Plan for the Project

No	Parameter	Existing Line (2017)	Improved Main Line (2023)	Remarks
1	Gauge: Double Tracks	1,000mm	1,000mm	
2	Length (km)	353km	353km	
3	Traction Power	Non-electrified	Non-electrified	
4	Axle Load for DEMU	less than 12.5ton	less than 20ton	
5	Construction Gauge / Rolling Stock Gauge			
	Construction Gauge			
a.	Height	3,810mm	4,300mm	
b.	Width	3,810mm	3,810mm	
	Rolling Stock gauge			
c.	Height	3,505mm	4,100mm	
d.	Width	2,818mm	3,000mm	
6	Horizontal curvature			
a.	Minimum radius	300m	Design Criteria 500m Design minimum value 300m	

No	Parameter	Existing Line (2017)	Improved Main Line (2023)	Remarks
7	Vertical alignment			
a.	Maximum gradient	6‰	10‰ Desirable 6‰	
8	Number of Stations	55	50	including Halt Station
9	Traffic Volume (Passenger-km/day)	2,089,247 (Estimated value in 2013)	10,190,618	Yangon-Mandalay whole section
10	Daily Ridership (No. of Passenger)	22,500 (Estimated value in 2013)	80,700	
11	Total number of Train per day	28	104	Trains on YM Line Only (Trains going to/from branch lines are excluded)
a.	Express Train	5 round trips	35 round trips	
b.	Local Train (including Mail trains)	5 round trips		
12	Speed			
a.	Maximum	48 - 69 kph	100 kph (DEMU)	
b.	Schedule	44 kph	77.5 kph or more	
13	Rolling Stock (Passenger Train)			
a.	Train composition and No. of Car	1 DEL + 14 coaches (max)	6 cars + 6 cars	
14	Safety System			
a.	Type of Signalling	Relay Interlocking Mechanical Interlocking	Relay Interlocking Electronic Interlocking	
b.	Train Control System	Absolute Block System	Absolute Block System Automatic Block System	
c.	Level Crossing	Manual Operated Level Crossing (97 crossings)	Automatic Level Crossing (79) Manual Level Crossing (17)	
15	Telecommunication	UHF, HF, OFC	UHF is improved	HF and OFC: out of scope
16	Station Platform			
a.	Minimum Length	***m	250m	for Express DEMU 12cars
b.	Height of platform above rail level	app. 150mm		
17	Maintenance facilities			
a.	Depot	Pyinmana, Naypyitaw, Thazi, Mandalay	Naypiytaw, Myouhan	Existing: for locomotive Improved: for DEMU
b.	Workshop	Myitnge	Ywathagyi (Phase 1)	
18	Power Supply	Limited to some stations only	All stations	

No	Parameter	Existing Line (2017)	Improved Main Line (2023)	Remarks
19	Track			
a.	Rail	BS75lbs(37kg/m)	50N (BS75lbs for stabling)	
b.	Sleeper	PC	PC	
c.	Ballast thickness	20cm	25cm	
d.	Fastening	e-Clip	FD or e-Clip	
e.	Rail joint	Fishplate	Welding and Fishplate	
20	Civil			
a.	Drainage	Partially installed	Basically Installed	
b.	Railway Bridge	Amount of Bridge No.is 71	Re-construction new bridge and/or box culvert	
21	Safety Fence	Partially installed	Partially installed	by MR component
22	Station Transfer Bridge Height			
a.	Pyinmana Station	Approx. 4,600mm > 3,810mm	Approx. 4,600mm > 4,300mm	
b.	Naypyitaw Station	Approx. 4,500mm > 3,810mm	Approx. 4,500mm > 4,300mm	
c.	Thazi Station	Approx. 4,400mm > 3,810mm	Approx. 4,400mm > 4,300mm	
23	ROB	5ROB	5ROB	

Source: JICA Study Team

The basic concept of technical utilisation in Japanese railway improvement projects is assumed as below.

a) Energy saving (Cost reduction and mechanisation of maintenance)

b) Lifelong duration of structures

c) Sustainable Operation & Maintenance

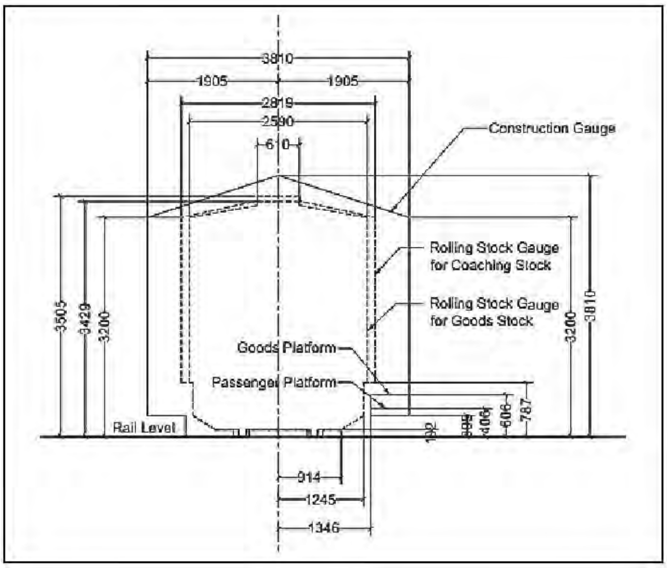
d) Renewal of facilities and improvement of function

The JICA Study Team proposes the utilisation of technology which saves the initial cost, enables sustainable operation & maintenance by local engineers, and ensures the renewal of facilities and improvement of function in the future.

4.2 Rolling Stock Gauge and Construction Gauge

4.2.1 Current MR Rolling Stock Gauge and Construction Gauge

The current MR rolling stock gauge and construction gauge is shown below in Figure 4.2.1



Source: MR

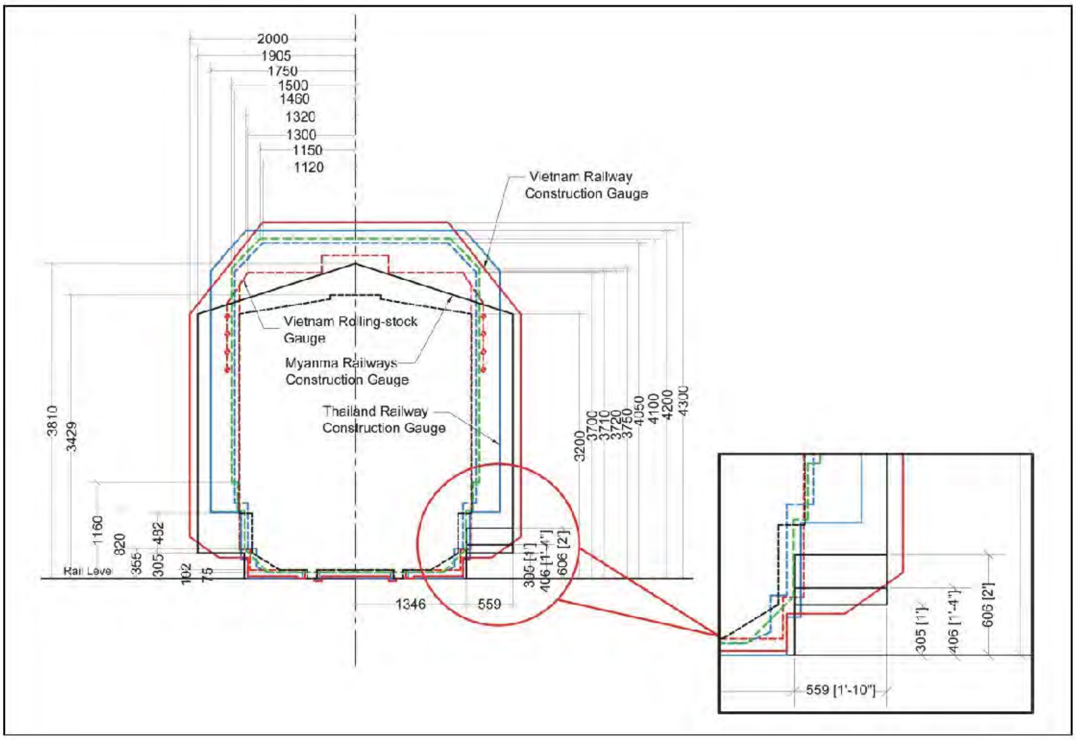
Figure 4.2.1 Current MR Rolling Stock Gauge and Construction Gauge

MR has two rolling stock gauges: for coaching stock and goods stock. Rolling stock gauges for coaching stock is wider and higher than for goods stock, however, the lower portion (close to platform) of both rolling stock gauges is the same. Both construction gauges are not different.

Compared to the other countries' construction gauge and rolling stock gauge, such as Thailand, Vietnam and Japan, there are the following issues:

- Height of MR rolling stock gauge and construction gauge is lower than other countries,
- Width of MR rolling stock gauge is the same as Vietnam and narrower than Thailand and Japan,
- In the lower portion (close to platform), although, Thailand rolling stock gauge located in the inside of MR rolling stock gauge, Japanese rolling stock gauge is located in the inner side slightly for MR construction gauge and Vietnamese rolling stock gauge is located outside for MR's. Therefore, in case that these countries' rolling stock run on the MR track, the bogies of those may hit the platform,
- Top of the Hi-Cube container (Height: 2,896mm) on the existing flat wagon (Floor height above rail level: 1,108mm [3'-7 5/8"]) may be higher than the MR construction gauge,
- Second hand rolling stock from Japan are bigger than rolling stock gauge, and require the modification of equipment on the roof, such as ventilators and air-conditioning units.

MR, Thailand, Vietnam and Japan rolling stock gauge and construction gauge is show in below Figure 4.2.2.



Source: JICA Study Team

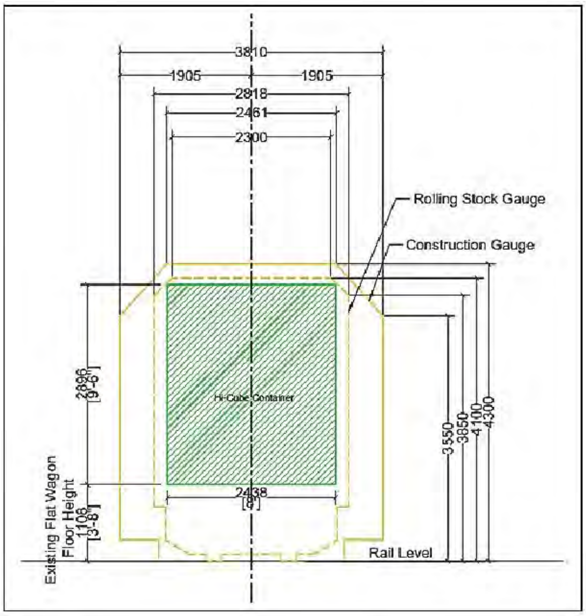
Figure 4.2.2 Rolling Stock Gauge and Construction Gauge of Other Countries

Therefore, to continue to utilize the current construction gauge and rolling stock gauge would be an obstacle to through-operation from other countries and expansion of transportation capacity.

4.2.2 Proposed Construction Gauge and Rolling Stock Gauge for Yangon-Mandalay Railway Phase I

As mentioned in the previous section, it is necessary to expand the construction gauge and the rolling stock gauge should be expanded. Therefore, the JICA Study Team proposes a new construction gauge and rolling stock gauge for the Yangon Mandalay Railway Improvement Project Phase I, considering ASEAN connectivity and expansion of transportation capacity. The concept of the new rolling stock gauge is given below:

- Width of rolling stock gauge: 3,000mm, enveloping other countries' rolling stock gauge and based on Japanese rolling stock gauge because MR may use a lot of second hand Japanese rolling stock even after rehabilitation,
- Height of rolling stock gauge: 4,100mm, enveloping other countries' construction gauge, considering transportation of Hi-cube containers using the exiting flat wagons and based on Japanese rolling stock gauge (Refer to Figure 4.2.3).



Source: JICA Study Team

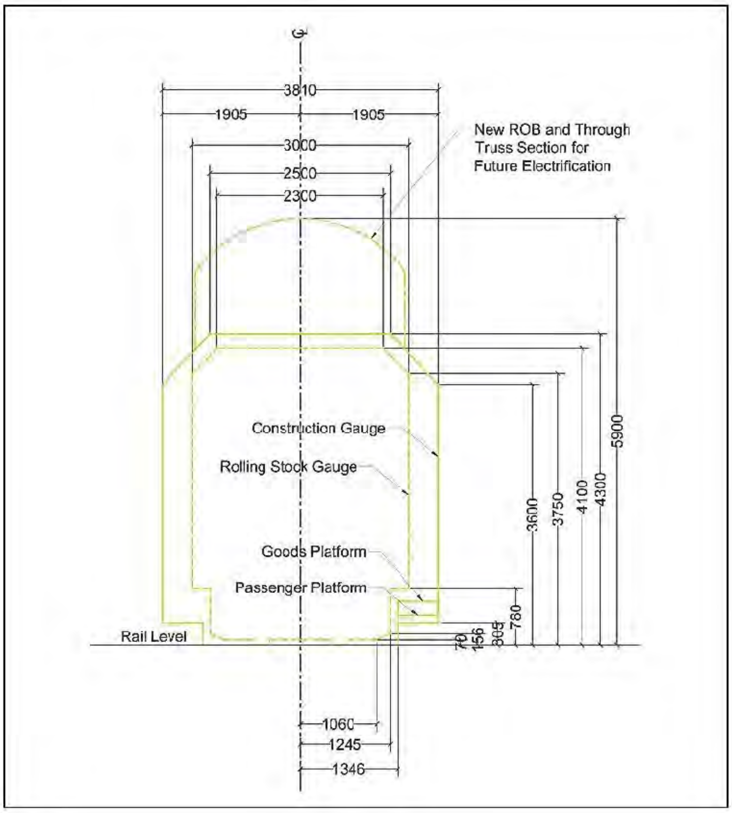
Figure 4.2.3 Proposed Rolling Stock Gauge considering Hi-Cube Container

And, clearance between rolling stock gauge and construction gauge should be at least 200mm at the top and 300mm at the sides, considering car body shaking and safety for train passengers.

Therefore, the concept of the new construction gauge is shown below:

- Width of Construction Gauge: 3,810mm, maintaining existing MR's construction gauge in order to avoid impact on the existing structures/facilities close to the track,
- Distance from rail center to Construction Gauge at Platform: 1,346mm, maintaining existing MR's construction gauge in order to avoid demolition of the existing platforms,
- Height of Construction Gauge: 4,300mm (5,900mm at the new ROB and through truss bridge sections, considering electrification in the future),
- Height of Construction Gauge at Platform: 406mm for passenger platform and 606mm for goods platform, maintaining the existing MR's Construction Gauge in order to avoid modification of existing platforms[1].

The proposed construction gauge and rolling stock gauge is shown below in Figure 4.2.4.



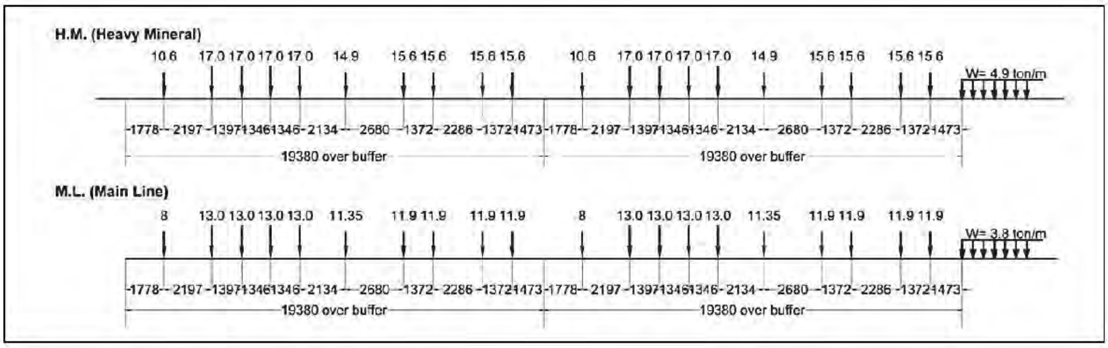
Source: JICA Study Team

Figure 4.2.4 Proposed Construction Gauge and Rolling Stock Gauge

4.3 Axel Load of Train

4.3.1 Current MR Axle Load

Regarding axle load for the existing bridge design in the Yangon Mandalay Railway, 17 t of H.M.(Heavy Mineral: maximum load 17.0t) or M.L. (Main Line: maximum load 13.0t) are applied. Standard loading is shown in the following page.



Source:MR

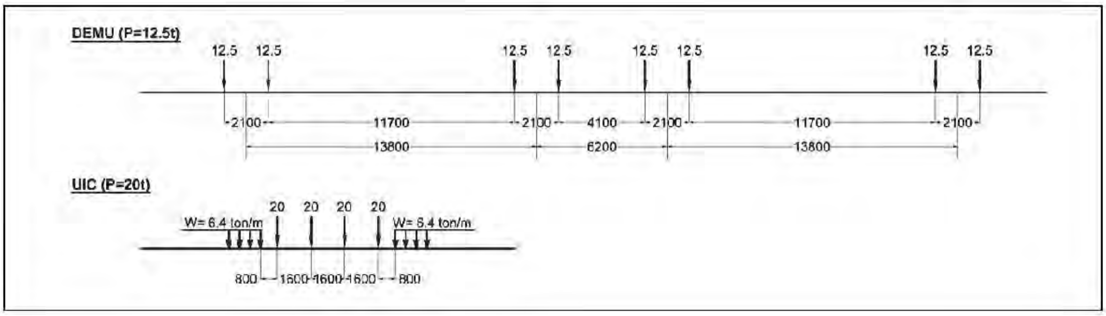
Figure 4.3.1 MR's Standard Loading (H.M. and M.L.)

4.3.2 Proposed MR Axel Load of Train for Yangon-Mandalay Railway

Considering introduction of new DEMU and ASEAN connectivity, the JICA Study Team proposes the following axle loads:

- New DEMU: 12.5 t Axle load
- UIC standard: 200 kN Axle Load, considering ASEAN connectivity

The proposed axle load of train is shown below in Figure 4.3.2.



Source: JICA Study Team

Figure 4.3.2 Proposed Axle Load of Train

UIC 200kN axle load shall be applied to design the new bridge, track and civil structures.

Chapter 5 Railway Project Plan

5.1 Train Operation

As is stated in Chapter 1, the goal of this railway improvement project is to achieve 100km/h speed train operation on the existing railway between Yangon and Mandalay by improving and modernizing its decrepit infrastructure and facilities and thereby to realize 8-hour travel time between the two biggest cities. In Phase 1, the travel time between Yangon Central Station and Taungoo Station of 267 km was estimated 3 hours and 9 minutes by the fastest train as a result of simulation. The travel time between Taungoo Station and Mandalay Station will be estimated in the detail design stage after the track layout is designed. Considering the distance of Phase 1 and that of Phase 2, it is likely that the travel time between Yangon and Mandalay will be within 8 hours.

The purposes of this chapter are

- To show the future plan of train operation,
- To demonstrate the draft DEMU operation plan and thereby to provide the preconditions to develop the depot plan, and
- To show the draft station track layout which can realize the 8 hour travel time and thereby to provide the preconditions to develop the civil and signalling plans.

5.1.1 Current Conditions of Train Operation

Among various current situations, the issues related with the modernization of train operation, especially high speed operation and high frequency operation, are stated below.

(1) Maximum Speed

According to an old document called "Working Time Book" edited on 1st August, 1962 by Burma Railways, the maximum speed was 64 km/h throughout the section at that time. However, due to the lack of maintenance on tracks and the age related deterioration of infrastructure, current maximum speed is less than 64 km/h for some sections. Table 5.1.1 shows the list of maximum speed for each section.

Table 5.1.1 Maximum Speed on the Main Line

Section	Maximum Speed (km/h)		Cause of Restriction
	Up	Dn	
Taungoo - Thargaya	56	56	Unstable embankment
Thargaya – Yeni	67	67	
Yeni - Pyinmana	64	64	
Pyinmana - Ywadaw	64	64	
Ywadaw - Kyidaungkan	48	48	Unstable embankment
Kyidaungkan - Shwemyo	64	64	
Shwemyo - Sinthe	64	48	Unstable embankment
Sinthe - Tatkon	64	48	Ditto
Tatkon - Magyibin	64	48	Ditto
Magyibin - Nyaunglun	64	48	Ditto
Nyaunglun - Yamethin	64	48	Ditto
Yamethin - Ingyinkan	69	48	Ditto
Ingyinkan - Shweda	69	48	Ditto
Shweda - Pyawbwe	48	48	Ditto
Pyawbwe - Shanywa	48	69	Ditto
Shanywa - Nyaungyan	56	69	Ditto
Nyaungyan - Nwato	56	69	Ditto
Nwato - Thazi	64	69	Ditto
Thazi - Ywapale	64	69	Ditto
Ywapale - Hanza	64	64	
Hanza - Thedaw	69	69	
Thedaw - Samon	69	69	
Samon – Kume Lan	64	64	
Kume Lan - Myohaung	69	69	
Myohaung - Mandalay	48	48	Public safety

(2) Speed Restriction by Gradient and at Curves

As the line between Yangon and Mandalay is laid in flat areas, there is no speed restriction on slopes. Also, when trains run based on the maximum speed prescribed in (1), there is no speed restriction in curves, but 100km/h operation in the future will require speed restrictions in the curves.

(3) Speed Restriction in Stations

Speed limits are prescribed for each station according to various conditions, such as types of points including its locking system, distance allowance for overrun, the isolation of sidings from main lines by approved means of isolation including trap points. According to the prescription by MR, passing trains have to reduce speed to 40 - 50km/h at many stations.

In main stations including Pyinmana Station, Thazi Station and Mandalay Station, speed is restricted to 32 km/h (16 km/h in Mandalay Station), due to the poor locking system of facing points.

(4) Block System and Block Stations

The Absolute Block System is applied to the section between Taungoo Station and Mandalay Station. This system is to secure the safety in which only one train is occupied in the block between two adjacent stations to prevent a collision accident.

A train driver needs a notice called an Authority to Proceed by the station master when leaving a block station. This system is called a Paper Line Clear in MR. When a train passes a block station, a station staff gives the notice by using a special tool made of bamboo as shown in Figure 5.1.1. This work would be impossible in 100km/h operation in the future.

Among the 55 stations in Phase 2, the following 7 stations are halt stations (non-block stations). Some trains stop at the designated place without platform where passengers get on and off.

- Kaytumadi
- Tharyargon
- Hteininn
- Dahattaw
- Khinban
- Odokkon
- Shanzu

Source: JICA Study Team

Figure 5.1.1 Receiving of Authority to Proceed at Kyauktaga Station (Phase 1)

At Shanzu Station, 7 trains stop every day and the average number of passengers getting on is 29 per day. Except Khinban Station where 17 passengers get on every day on average, almost no passengers use the other stations.

(5) Level Crossing

Some particular issues are stated here that would affect the modernization of train operation.

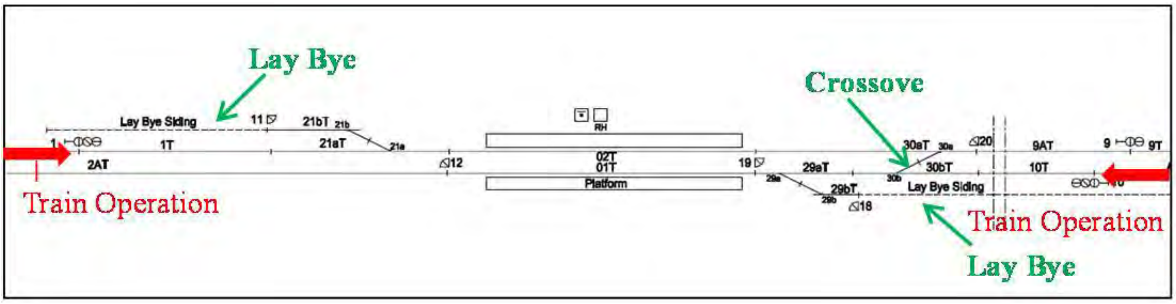
Firstly, in many cases, to recognize an approaching train and thereafter to close the gates are undertaken by a gateman at the direction of the station master through a phone or by his visual observation without any systematic support. As the line is modernized, the interval will be shortened from the time when he acknowledges an approaching train to the time when it reaches the level crossing as the result of the 100km/h operation. Also, the train frequency is likely to be increased. These factors will not only increase the burden on the gatemen but also cause an emergency stop of a train or, in the worst case, a level crossing accident due to the delay of the gateman's operation.

Secondly, at many level crossings, the Proceed signal is given to a train driver by a gateman by using his green flag or by his green light at night after he closes the gates and secures the safety in the level crossing. As the interval is shortened from the time when a train driver recognizes the green flag to the time when the train reaches the level crossing in the future 100km/h operation, the train driver's visibility as well as safety for gatemen themselves shall be taken into consideration.

(6) Shunting in a Station

When a fast train passes a slow train or some vehicles are stabled at a station, a loop line is utilized in some cases, but in other cases MR uses a siding called "Lay Bye" as is shown in Figure 5.1.2. The "Lay Bye" is effective to improve safety by not using facing points for main line operation and thus to minimize the speed reduction of a passing train. On the other hand, passing of a slower train by a faster train or stabling of vehicles is performed by shunting on main lines. This could be possible only when train speed and frequency are low like today.

If one of the two lines, Up and Down lines, is blocked for some reasons such as accident and disaster, MR sometimes operates both Up trains and Down trains on the other available line. In this case, a train has to cross between the Up line and Down line at a station. In order to avoid facing points in normal operation, the track layout of the crossover between the two lines is as shown in Figure 5.1.2. This case also requires the shunting on main lines.



Source: JICA Study Team

Figure 5.1.2 Example of Lay Bye and Crossover (Tawa Station: Phase 1)

(7) Automatic Train Protection System

MR has never introduced a backup system for train drivers to avoid a SPAD (Signal Passed At Danger). This safety issue is dependent only on the caution of drivers and assistant drivers.

(8) Traffic Management

All the important decisions regarding traffic management are made by the Operation Control Center (OCC) in the MR Headquarters, such as the cancellation of a train service, temporary stop of a train at a station, and the recovery plan in case of accidents and traffic disturbances. The OCC in the Headquarters sends commands to the OCC of each division, and each OCC sends commands to the related station masters in its division directing them to execute the necessary operation.

Source: JICA Study Team

Figure 5.1.3 Taungoo OCC

Although these OCCs don't capture information regarding the location of each train on time, an ongoing Grant Aid by JICA, "the Project for Installation of Operation Control Center System and Safety Equipment (OCC Project)", will provide a centralized train monitoring system between Yangon and Pyuntaza by the end of Phase 1 of this project.

These OCCs and the stations between Yangon and Taungoo can communicate with each other through cable and radio telecommunication. On the other hand, train operation is basically based on the signals of each station. When a special command to a train driver is required, it is delivered from the station master as a paper notice. There exists no means of radio communication to train drivers from OCCs or station masters.

(9) Passenger Transport

Regarding the current express trains on Yangon Mandalay Line, there are 3 round trips between Yangon and Mandalay and 2 round trips between Yangon and Naypyitaw every day. All the trains are the coach train pulled by a diesel electric locomotive (DEL). For some services, a train composing of a new Chinese DEL and new Chinese coaches started operation in 2016 (Figure 5.1.4). Table 5.1.2 shows the travel time of the current express trains between Yangon and Mandalay.

Table 5.1.3 shows the current local trains on Yangon Mandalay Line.

Source: JICA Study Team

Figure 5.1.4 Express Train by new Chinese DEL and Coaches

There are other trains operated on Yangon Mandalay Line departing and arriving at Naypyitaw Station going into a branch line at a station on Yangon Mandalay Line.

Table 5.1.2 Travel Time of Current Express Trains (Yangon - Mandalay)

Train Number	Travel Time
3 UP, 4 DN (Night train)	14 hours 45 minutes
5 UP, 6 DN (Night train)	14 hours 00 minutes
11 UP, 12 DN (Day train)	14 hours 50 minutes

Source: JICA Study Team

Table 5.1.3 Local Trains (between Taungoo and Mandalay)

Origin & Destination	Number of Services
Yangon - Mandalay (Mail Train)	1 round trip
Yangon - Thazi (Main Train)	1 round trip
Taungoo - Thazi	1 round trip (every 2 days)
Thazi - Myohaung	1 round trip
Pyinmana - Tatkon	2 round trips

Source: JICA Study Team

(10) Freight Transport

Any freight train does not have a timetable. The departure time at the origin station is decided when the freight train has been set up after loading and the OCC finds an adequate time between passenger trains. After leaving the origin station, the freight train travels as far as the operation does not disturb passenger trains. When a passenger train approaches to the freight train from behind, the freight train has to wait for the approaching train at a station on the way.

Currently 2 to 5 round trips of freight trains are daily operated between Mahlwagon Station and Myohaung Station. Also, some wagons are connected with local trains described in (9).

5.1.2 Future Plan of Train Operation

(1) Maximum Speed

As is mentioned in Chapter 1, the maximum speed of the line will be set 100km/h for the whole main line.

(2) Speed Restriction

As the section between Taungoo and Mandalay is flat, there will be no speed restriction by slope. In case the speed restriction by curve is inevitable due to topographical conditions, the track layout should be taken care of in such a way that the curve will not affect the travel time as much as possible.

(3) Speed Restriction in Stations

For each station, necessary measures including the interlocking of signals and points and safety sidings should be taken so that trains can pass the station without reducing its speed. However, in the large scale of stations, namely Pyinmana Station, Thazi Station and Mandalay Station, to set safety sidings will shorten the effective length of lines and thus the JICA Study Team proposes not to set safety sidings in these stations and to remain the speed restriction as it is.

(4) Block System and Block Stations

The Absolute Block System will be adopted between Taungoo and Mandalay as it is today. The current method "Paper Line Clear" shall not be used but the train driver shall secure the block to the next station by the Proceed aspect of the Starter signal.

Among the 7 halt stations, the 5 stations where almost no passengers use are expected to be abolished so that the travel time on that block section will be shorter and the line capacity will not become smaller. Khinban Station located between Thedaw Station and Samon Station is expected to remain as a station. In order not to increase the travel time between Thedaw Station and Samon Station and to keep enough line capacity in the future, the JICA Study Team proposes that Khinban Station become a block station. This means that the current block between Thedaw Station and Samon Station will be divided into 2 block sections.

Shanzu Station is also expected to remain a station for passengers. Considering that the distance between Myohaung Station and Mandalay Station is rather short, the JICA Study Team proposes that the Automatic Block System be installed between Myohaung Station and Mandalay Station instead of the Absolute Block System and that Shanzu Station remain as a halt station as it is. This modification is expected to require less cost compared with the case that Shanzu Station becomes a block station, while the line capacity is almost the same for the two cases.

(5) Level Crossing

To keep the safety for the 100 km/h operation, the level crossings inside stations and those located between the Distant signal and the Outer signal are expected to be equipped with level crossing safety equipment as is the same as the design in Detailed Design for Yangon-Mandalay Railway Improvement Project Phase I (YM-D/D(1)). Even for the level crossings between stations, the JICA Study Team will consider to install the level crossing safety equipment on them if power supply is available. For the purpose of preventing level crossing accidents, the gatemen of all the official level crossings whether or not they are equipped with the safety equipment are to use a portable radio device so that they can get train approaching information from nearby station masters. Details are stated in Section 5.12.

According to the General Rules of MR, gatemen are supposed to show the Proceed signal by hand or by light after confirming that the gate has been closed and the train driver must stop before the level crossing if he cannot recognizes the Proceed signal. For most of the level crossings which are not to be equipped with the level crossing safety equipment, the train driver can recognize the signal even in the 100 km/h operation as they are located in a long straight section. Before MR starts 100km/h operation, however, MR should educate train drivers concerning this rule again by taking necessary measures such as reducing speed since 100 km/h operation might reduce visibility.

(6) Shunting in a Station

Current lay bye lines are expected to be abolished in principle.

(7) Automatic Train Protection System

As is the same as Phase 1, the signals where train driver's human errors might cause serious accidents are expected to be equipped with the Automatic Train Protection System. The specifications should be the same as those of Phase 1 so that the on-board equipment installed in Phase 1 is able to be used for the Phase 2 section.

(8) Traffic Management

While the OCC Project will install the Operation Control Center System for the section between Yangon Central Station and Pyuntaza Station, the rest of the whole section of Yangon Mandalay Line, including the Phase 1 section between Nyaung le bin Station and Taungoo Station, is expected to be covered by an Operation Control Center System.

As the current radio telecommunication system is improved in this project, train drivers, level crossing gatemen and maintenance staff are expected to communicate with station masters and OCC through a portable radio device in order to contribute to the safety and stable train operation.

(9) Passenger Transport

As was planned in Phase 1, a plenty of DEMU cars are to be installed for express trains of Yangon Mandalay Line and also some local type of DEMU cars are to be installed for local trains between Yangon Central Station and Bago Station.

Regarding the local trains on the sections north from Bago Station, locomotive hauled coach trains will be operated as today. These vehicles are out of scope of this project.

(10) Freight Transport

Regarding the freight transport, container transport is expected to increase in the future. As is stated in 5.15, however, MR has launched a Public Private Partnership (PPP) project for container transport with industrial and domestic transport companies. In this regard, the container transport is out of scope of this project. However, the track layout of the related stations should be designed in such a way that container trains will be able to go into and go out of the dry port by the PPP project. Under the PPP project, new dry ports are being constructed at Myitnge Station. The detail information regarding this PPP project is stated in 5.15.2 (3) 2).

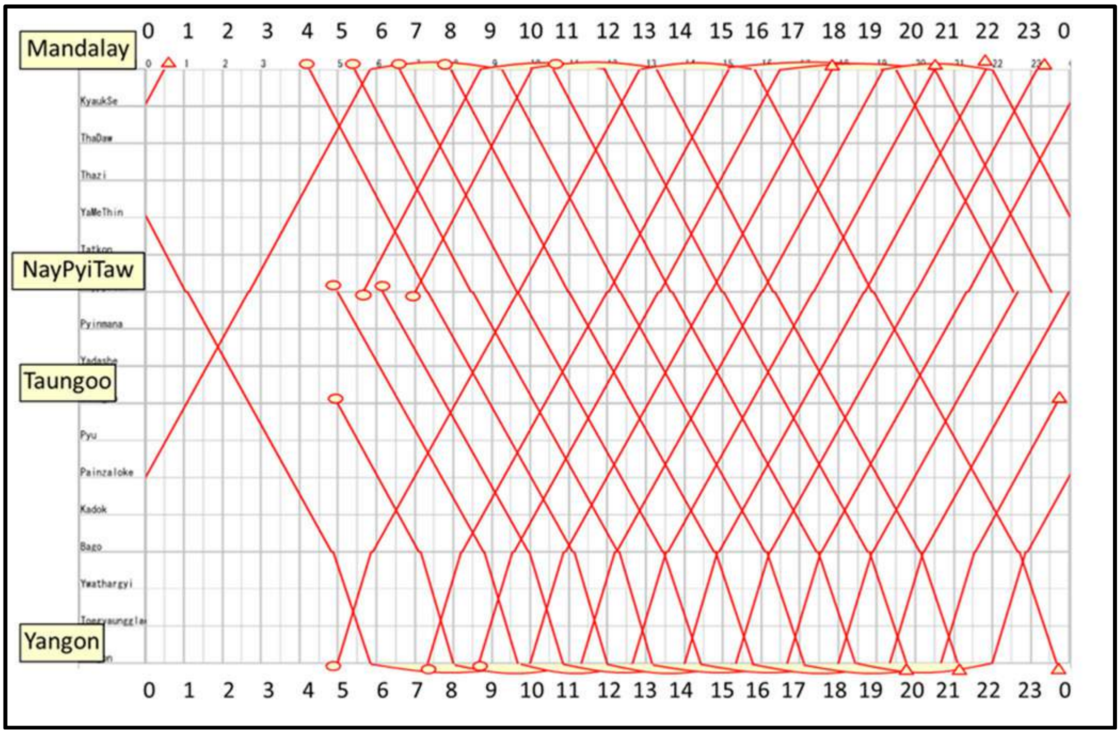
Besides, the development of Myohaung Goods Yard will be an important issue of this project since, as is mentioned in 5.11, a new DEMU depot is expected to be developed in the current goods area by rearranging the facilities in this area.

For other stations, the JICA Study Team will propose the station track layout while considering the current loading and unloading works in the stations.

5.1.3 Number of DEMU Cars to be Procured

Regarding the DEMU to be procured in this project, as Chapter 2 showed that there is no significant difference in the transport demand forecast from the result in YM-D/D(1), the JICA Study Team proposes to use the same transport plan and thus the same number of DEMU cars proposed in YM-D/D(1) in terms of Express DEMU. Regarding the Local DEMU between Yangon and Bago, it was decided not to procure the rolling stock after the discussion with MR.

Figure 5.1.5 shows an example of the express DEMU operation at the commencement of Phase 2 as the result of YM-D/D(1).



Source: JICA Study Team

Figure 5.1.5 Example of Express DEMU Operation (Proposal by JICA Study Team)

Table 5.1.4 shows the number of vehicles to be required and to be procured in Phase 2. After the discussion with MR, it was determined that the number of the Express type of DEMU cars is 180.

Table 5.1.4 Number of Vehicles to be Required and Procured in Phase 2
(Proposal by JICA Study Team)

	Number of Vehicles Required	Number of Vehicles Procured in Phase 2
Express DEMU	DEMU (6 cars＋6 cars) × 17 trainsets = 204 cars	180 cars

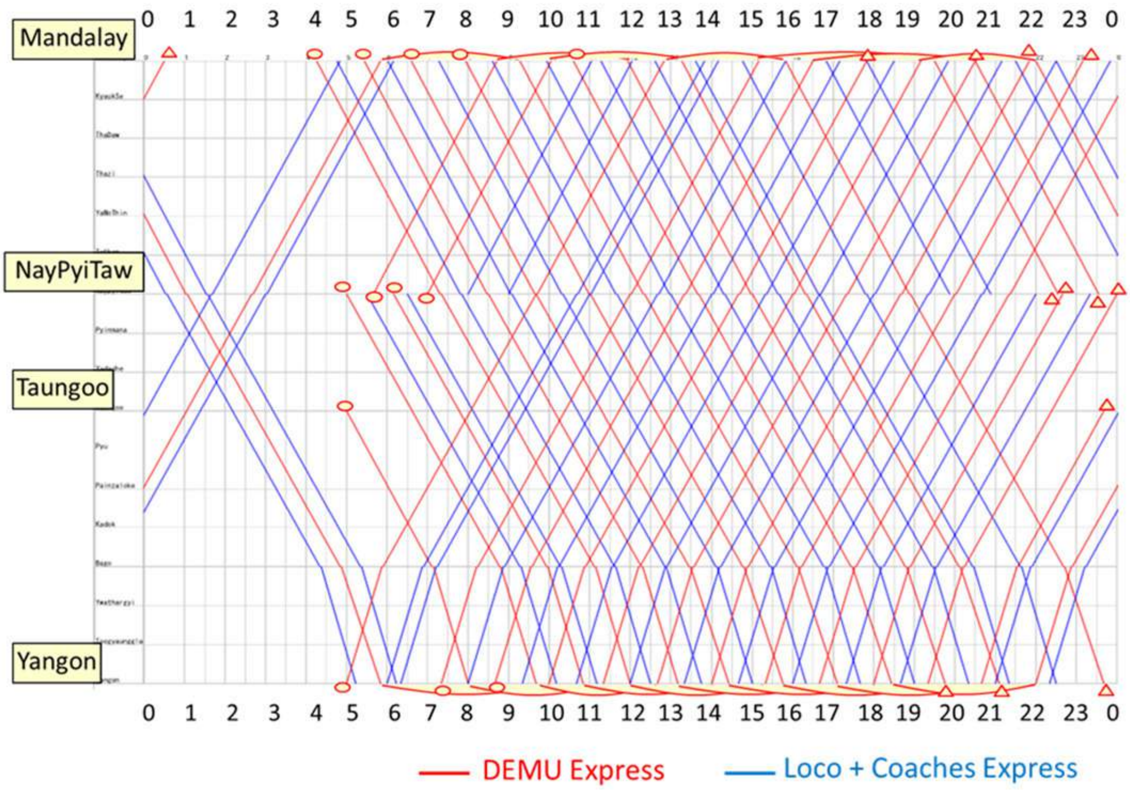
Source: JICA Study Team

In order to meet the increasing travel demand due to the improvement of the YM Line, MR is expected to prepare locomotives and coaches for serving passenger coach trains for the passengers not using DEMU trains. Table 5.1.5 shows the detail information.

Table 5.1.5 Number of Train Services in Phase 2 (Based on Table 5.1.4)

Section	Travel Demand (Section with maximum demand)	Express DEMU (Capacity 620)	Coach Train by MR (Capacity 640)
Yangon – Bago	21,934	13	22
Bago – Taungoo	20,893	13	20
Taungoo - Mandalay	22,182	12	23

Source: JICA Study Team



Source: JICA Study Team

Figure 5.1.6 Example of Express Operation (Proposal by JICA Study Team)

Table 5.1.5 shows the number of DEMU trains and the number of coach trains to be provided by MR. The decision how many express coach trains should be set and how many local coach trains should be set will be made by MR. Suppose that the number of express coach trains is the same as DEMU, 13 trains, the draft express operation plan is demonstrated in Figure 5.1.6.

Other than these express trains, low speed trains such as local trains and freight trains are to be operated. The express trains will have to pass these low speed trains at stations. In the coming detailed design stage, it will be necessary to examine whether the operation plan is feasible or not by the station track layout plan stated in 5.1.4 below.

5.1.4 Draft Station Track Layout

It is necessary to decide the station track layout considering the two points below, while following the various rules of MR.

- Line Capacity

  When there are various types of trains with different speed, there need stations where a fast train passes a slow train. On the other hand, if there are many stations with such a function, expensive facilities including turnouts and complex interlocking systems are required and thus the total project cost will be higher.

- Works at Stations including Shunting Works

  Current loading and unloading works of freight trains including ballast transport and other types of works at each station should be taken into consideration. Also, MR's future plans for freight transport should be considered, if any.

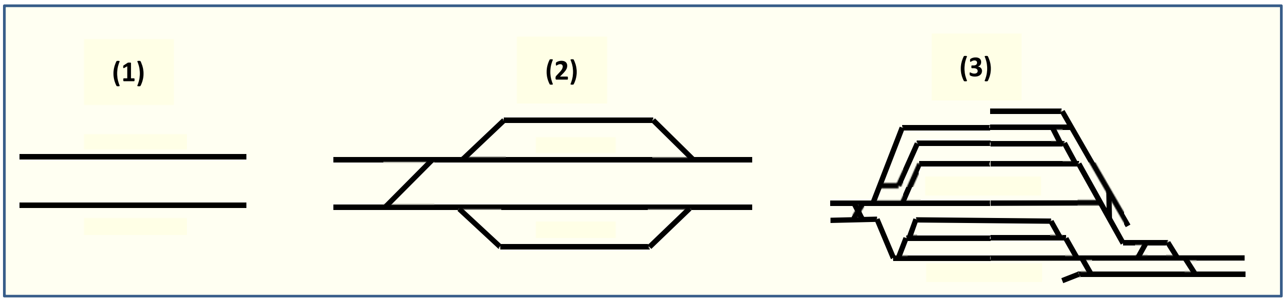
The JICA Study Team visited all the stations to make a survey with the support by MR in this study. The JICA Study Team interviewed the station master about the current works of each station. The JICA Study Team developed the draft track layout plan of each station, taking the opinions of the station master and a traffic manager of MR into consideration. Attachment 5-1 shows the draft station layouts the JICA Study Team proposes. The outline of the proposal is summarized as follows.

The track layouts could be classified into the following three types.

(1) Up and Down main lines only

(2) Up and Down main lines with a few loop lines

(3) Up and Down main lines with lots of loop lines and/or stabling lines



Source: JICA Study Team

Figure 5.1.7 Station Track Layout Classification

For 49 stations, excluding 5 block stations to be abolished and 1 block station to be remained from the 55 stations in Phase 2, Table 5.1.6 shows the number of stations of each type of track layout.

Table 5.1.6 Breakdown of Draft Station Track Layouts

Type	No. of Stations	Station Name
(1)	15	-
(2)	28	-
(3)	6	Pyinmana, Naypyitaw, Thazi, Myitnge, Myohaung, Mandalay
Total	49	

Source: JICA Study Team

Although this study does not include the simulation on the time chart (diagram) to find out whether these station track layouts are workable to operate the trains in the future as YM-D/D(1) did, it is assumed that these drafts are enough to meet the demand forecast in 2023 and in 2030, considering the ratio of (1), (2) and (3). Furthermore, the draft station track layouts are required to be confirmed from the civil and signalling points of view.

These works will be conducted in the detailed design stage. This means that the final station track layouts will be decided in the detailed design stage. The outputs in Appendix 5-1 are used provisionally for the study of each field, especially for estimating the project cost.

Finally, some stations to be specified are listed.

➢ Pyinmana Station

- Due to the level crossings on the Yangon side and on the Mandalay side, it is difficult to keep an adequate effective length of each line. To keep the effective length as long as possible, the JICA Study Team proposes not to install safety sidings and thus to remain the speed restriction in the station as today.
- For the same reason, a short siding currently located between Track 2 and Track 3 on the Mandalay side is proposed to be removed.

- Ywadaw Station
  - Ywadaw Station will be the freight terminal in the Naypyitaw area. Details are stated in 5.15.3 (1).
- Sinthe Station
  - The facilities in the station for the branch line to Pinlaung Station (Division 4) are to be removed.
- Pyawbwe Station
  - The branch line to Lintsinkon Station is to be remained.
- Thazi Station
  - There are two tracks to the branch line to Myingyan Station, the track previously used and the track currently used. In this project, the track previously used, which is located on the Yangon side, is to be remained and the track currently used is to be removed.
  - Five (5) stabling lines are to be removed to install freight facilities. Details are stated in 5.15.3 (1).
- Ywapale Station and Hanza Station
  - A water tank wagon is stabled for the station staff in the lay bye line in front of the station building since this area is lack of water. The JICA Study Team proposes to quit this service and then to remove these lay bye lines.
- Myitnge Station
  - The level crossing next to the platform going to Myitnge Workshop is to be removed and construct an overpass instead.

5.2 Track Alignment

5.2.1 Current Conditions of Track Alignment

(1) Curve Radius

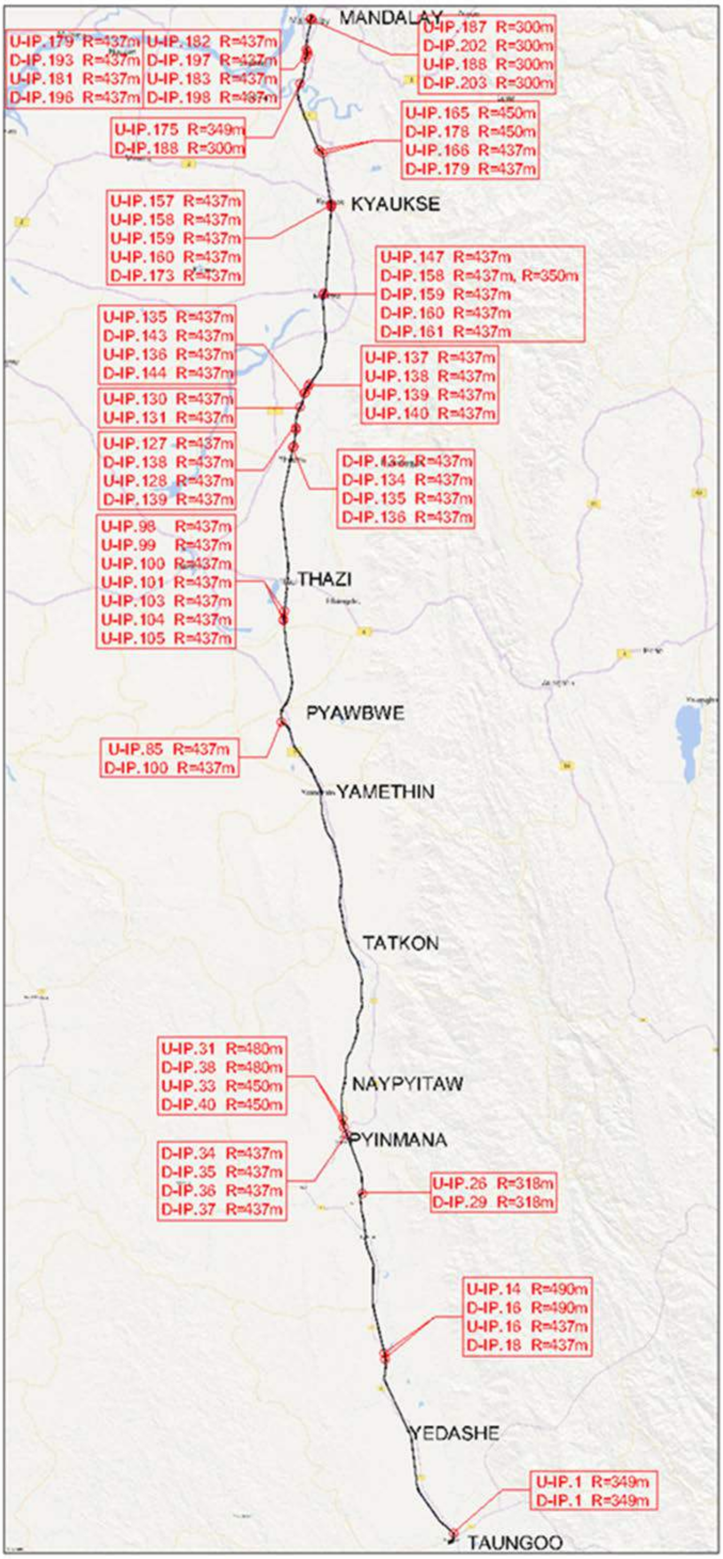
Reproduction of the existing alignment is considered based on the Track Layout Drawing obtained from MR and Satellite Imagery. The locations of curves in the main line between Taungoo Station and Mandalay Station are 159 for the Up Line and 167 for the Down Line. Among these curves, there are 38 and 34 curves with less than 500m radius, which is the restriction for the 100-km/h operation of DEMU train, for the Up Line and Down Line, respectively.

Table 5.2.1 Number of Curves (between Taungoo Station and Mandalay Station)

		Up Line	Down Line
All Curves		159	167
	800m≦R	83	84
	500m≦R<800m	38	49
	R<500m	38	34

Source: JICA Study Team

In this project, it was confirmed that the existing alignment drawings prepared based on satellite Images are mostly congruous with the current conditions of the project site as the result of the site survey. However, there were some places regarded not to be congruous with the conditions of the project site at some points of curves. It is necessary to examine the alignment improvement plan using topographical survey result in the Detail Design stage.

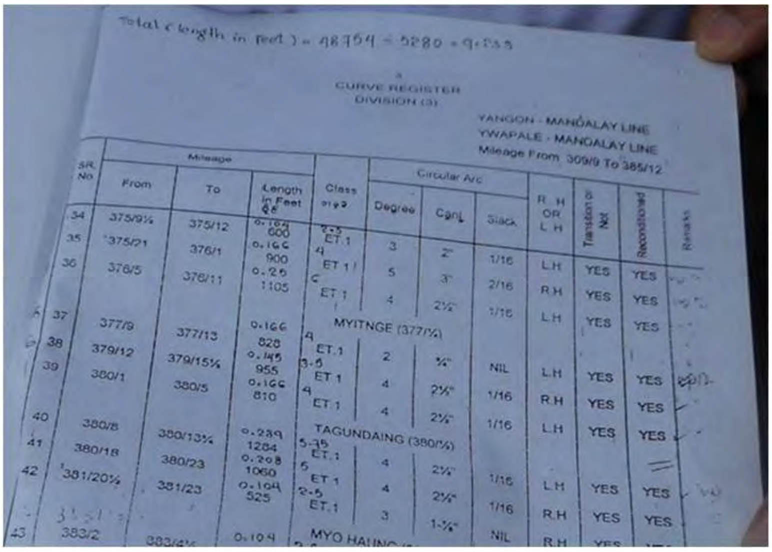


Source: JICA Study Team

Figure 5.2.1 Location of Transition Curves with Less Than 500m Radius

Although transition curve is not described in the Track Layout Drawing, JST was able to confirm the Curve Ledger possessed by the track maintenance division, from the MR staff accompanying the site survey. According to this, it is found out that transition curve is inserted in the existing line. Since there is no description regarding transition curve length in this Curve Ledger, it is unclear what length of transition curve is inserted with each curve. However, the design maximum speed is indicated to be 45 mph (= approximately 72.4 km/h) in the MR construction regulation (Burma Railways Manual of the Engineering Department). Therefore, it is expected that the transition curve length corresponding to this speed is inserted.

In any case, in order to operate at 100 km/h, extension of the transition curve corresponding to this speed is needed.



Total (length in feet) = 48754 ÷ 5280 = 9.235

CURVE REGISTER
DIVISION (3)

YANGON - MANDALAY LINE
YWAPALE - MANDALAY LINE
Mileage From 309/9 To 385/12

SR. No	Mileage From	Mileage To	Length in Feet	Class	Circular Arc Degree	Circular Arc Cant	Circular Arc Slack	R.H OR L.H	Transition or Not	Reconditioned	Remarks
34	375/9½	375/12	0.104 600	2-5 ET.1	3	2"	1/16	L.H	YES	YES	
35	375/21	376/1	0.166 900	4 ET 1	5	3"	2/16	R.H	YES	YES	
36	376/5	376/11	0.25 1105	C ET 1	4	2½"	1/16	L.H	YES	YES	
	MYITNGE (377/½)										
37	377/9	377/13	0.166 828	4 ET.1	2	½"	NIL	L.H	YES	YES	
38	379/12	379/15½	0.145 955	3-5 ET 1	4	2½"	1/16	R.H	YES	YES	
39	380/1	380/5	0.166 810	4 ET 1	4	2½"	1/16	L.H	YES	YES	
	TAGUNDAING (380/½)										
40	380/8	380/13½	0.239 1264	5-75 ET.1	4	2½"	1/16	L.H	YES	YES	
41	380/18	380/23	0.208 1060	5 ET 1	4	2½"	1/16	R.H	YES	YES	
42	381/20½	381/23	0.104 525	2-5 ET.1	3	1-½"	NIL	R.H	[illegible]	[illegible]	
43	383/2	383/4¼	0.104	[illegible]							
	MYO HAUNG [illegible]										

Source: JICA Study Team

Figure 5.2.2 Curve Ledger possessed by the track maintenance division

(2) Gradient

According to the Track Layout Drawing, vertical alignment is smooth through the whole line, and the maximum gradient is 6‰. Gradient will be examined carefully through the site survey result.

5.2.2 Recommendation for Track Alignment

(1) Design Standard for Track Alignment

The speed limit on curve is decided by gauge and vehicle performance. For the DEMU and passenger trains, the relation between curve radius and speed limit is shown in Table 5.2.2. For the 100 km/h operation of DEMU train, the curve radius of 500 m or more is needed. On the other hand, for the 100 km/h operation of limited express passenger train, the curve radius of 800 m or more is needed.

Table 5.2.2 Speed Limit on Curve

Curve Radius (m)	Speed Limit (km/h)	
	DEMU	Passenger Train
800 <		100
700-800		95
600-700		90
500-600	100	85
450-500	95	80
400-450	90	75
350-400	85	70
300-350	75	65
250-300	70	60
200-250	60	50
150-200	50	40
100-150	40	30

Source: JICA Study Team

Moreover, the Design Standard for Track Alignment is shown in Table 5.2.3 based on the Detailed Design for Yangon-Mandalay Railway Improvement Project Phase I. The maximum design speed is 100 km/h in case of limited express, and 70 km/h in case of local and freight train.

Although transition curve length changes largely by the way of setting of actual cant, in this survey, actual cant is set to 70% of equilibrium cant as well as the view of the phase 1.

Table 5.2.3 Design Standard for Track Alignment

Item		Standard	Remarks
Maximum Design Speed	Limited Express	100 km/h	There are DEMU and passenger trains as Limited Express.
	Local, Freight train	70 km/h	
Gauge		1000 mm	
Rail	Main Line, Passing Track	JIS50N	
	Siding, Depot	BS75	
Rolling Stock Gauge		W3000 mm×H4100 mm	
Construction Gauge		W3810 mm×H4300 mm	
Minimum Curve Radius	Main Line	500 m	Exceptional case: Absolute minimum of 160 m at the station
	Along Platform	400 m	Straight in principle
	Depot	100 m	
Transition Curve	Shape	Cubic Parabola	
	Length	L1=400*Cm L2=8.536*Cm*V (7.469*Cm*V) L3=9.603*Cd*V (7.469*Cd*V) Where, Cm : Applied Cant (m) Cd : Cant Deficiency (m) V : Train Speed (km/h)	( ) ; Exceptional case
Maximum Gradient	Main Line	10‰	Desirable 6‰
	Station, Depot, Stabling track	2.5‰ Exceptional case 5‰	Desirable 0‰
Distance between Track Centers (Main Line)		4.42 m	Existing condition
Turnout	Main Line	1:12, 1:10	
	Depot	1:8	

Source: JICA Study Team

(2) Recommendation for Track Alignment

Vertical alignment is smooth through the whole line, and all of gradients are 6‰ or less according to the Track Layout Drawing. Regarding the necessity of vertical alignment improvement, it is judged by topographical survey result. And horizontal alignment improvement is described below in this survey.

1) Items of Curve Improvement

In this survey, horizontal alignment improvement is examined about the following items.

- Improvement of curve radius for 100km/h operation of DEMU
- Extension of transition curve length for 100km/h operation of DEMU
- Improvement of horizontal alignment before and after bridge, related to bridge relocation plan

The improvement of curve radius and the extension of transition curve length for the 100-km/h operation of DEMU is the target, and 100-km/h operation of the limited express passenger train is not the target of improvement. The improvement of curve radius is to make the curve with radius less than 500m to radius 500m or more, 38 locations in the Up Line and 34 locations in the Down Line are the targets for study. As for the extension of the transition curve length, all the curves are the targets for study, i.e., 159 locations in the Up Line and 167 locations in the Down Line.

As for study of the curve improvement plan, the efficient and realistic plan is examined without land acquisitions and big impact on environmental social consideration. Therefore, in cases where new land acquisition is needed when curve radius is improved to 500m or more, it will be improved to the curve radius as large as possible to fit within ROW.

In addition, the horizontal alignment improvement in this survey targets the main line, and the improvement of station yard is not included.

2) Study Results of Horizontal Alignment Improvement

As the result of the horizontal alignment improvement, as shown in Table 5.2.4, the number of curves with the radius less than 500m is 7 for the Up Line and 6 for the Down Line. The number of curves after improvement decreases because there are places where two adjacent curves are integrated into one curve. The study results of each horizontal alignment improvement are shown in Table 5.2.5-Table 5.2.11. The current conditions of curve are shown in the left-hand column in table, and the improvement plans are shown in the right-hand column. Moreover, the values of the red figures in table mean that the existing curve radius is less than 500m, comments of blue figures in the improvement plan column mean what needs to be adjusted and matched in the Detailed Design stage.

Table 5.2.4 Number of Curves after Alignment Improvement

		Current Conditions		After Improvement	
		Up Line	Down Line	Up Line	Down Line
All Curves		159	167	156	160
	800m≦R	83	84	100	109
	500m≦R＜800m	38	49	49	45
	R＜500m	38	34	7	6

Source: JICA Study Team

Table 5.2.5 Improvement Plan of Horizontal Alignment (1 of 7)

Current Condition											Improvement Plan
UP LINE					DOWN LINE					Remarks	
No.	IP	Curve Location	Curve Direction	Radius (m)	No.	IP	Curve Location	Curve Direction	Radius (m)		
1	U-IP.1	269K369M	Left	349.28	1	D-IP.1	269K370M	Left	349.28		Only extension of transition curve length, due to access road to Monas (TCL=60m)
2	U-IP.2	271K176M	Left	873.21	2	D-IP.2	271K180M	Left	873.21	Bridge in curve (No.273)	Extension of transition curve length (TCL=60m)
3	U-IP.3	272K363M	Right	873.21	3	D-IP.3	272K367M	Right	873.21		Extension of transition curve length (TCL=60m)
4	U-IP.4	273K454M	Right	873.21	4	D-IP.4	273K458M	Right	873.21		Extension of transition curve length (TCL=60m)
5	U-IP.5	282K054M	Right	873.21	5	D-IP.5	282K056M	Right	873.21	Close to Kyungon sta.	Extension of transition curve length (TCL=60m) It is necessary to coordinate with station layout plan, and to check distance between service track to Army Base.
6	U-IP.6	293K574M	Left	873.21	6	D-IP.6	293K575M	Left	873.21	Bridge in curve (No.291A)	Extension of transition curve length (TCL=60m)
7	U-IP.7	306K480M	Right	873.21	7	D-IP.7	306K487M	Right	873.21	Bridge in curve (No.305A)	Extension of transition curve length (TCL=60m)
8	U-IP.8	306K804M	Left	873.21	8	D-IP.8	306K806M	Left	873.21		Extension of transition curve length (TCL=60m) It is necessary to coordinate with No.306 bridge relocation plan.
					9	D-IP.9	307K201M	Left	873.21		Extension of transition curve length (TCL=60m) It is necessary to coordinate with No.306 bridge relocation plan.
					10	D-IP.10	307K397M	Right	873.21		Extension of transition curve length (TCL=60m)
9	U-IP.9	307K660M	Right	750	11	D-IP.11	307K667M	Right	750	Close to bridge (No.307)	Integrate three consecutive curves into one curve (R=830m, TCL=60m) It is necessary to coordinate with station layout plan at end side of curve.
10	U-IP.10	307K880M	Right	750	12	D-IP.12	307K886M	Right	750	Close to bridge (No.307A)	
11	U-IP.11	308K026M	Right	500	13	D-IP.13	308K031M	Right	500	Close to bridge (No.307A) Close to Swa sta.	
12	U-IP.12	310K738M	Left	582.14	14	D-IP.14	310K743M	Left	582.14	Bridge in curve (No.312)	Extension of transition curve length (TCL=85m)
13	U-IP.13	311K681M	Right	620	15	D-IP.15	311K687M	Right	620		Extension of transition curve length (TCL=85m)
14	U-IP.14	312K221M	Left	490	16	D-IP.16	312K227M	Left	490		Improved to R=500m, TCL=90m
15	U-IP.15	312K866M	Right	600	17	D-IP.17	312K872M	Right	600	Bridge in curve (No.315)	Extension of transition curve length (TCL=80m)
16	U-IP.16	313K576M	Left	436.6	18	D-IP.18	313K582M	Left	436.6	Close to bridge (No.317)	Improved to R=500m, TCL=90m
17	U-IP.17	324K723M	Right	873.21	19	D-IP.19	324K729M	Right	873.21		Extension of transition curve length (TCL=60m)
18	U-IP.18	333K769M	Left	720	20	D-IP.20	333K776M	Left	720	Bridge in curve (No.343)	Extension of transition curve length (TCL=65m)
19	U-IP.19	337K710M	Right	873.21	21	D-IP.21	337K717M	Right	873.21	Close to Thawati sta.	Extension of transition curve length (TCL=60m) It is necessary to coordinate with station layout plan.
20	U-IP.20	338K584M	Right	600	22	D-IP.22	338K633M	Right	750	Close to Thawati sta.	UP : "Exceptional case" is applied to transition curve length, due to turnout before curve (TCL=70m). It is necessary to coordinate with station layout plan. DN : It is difficult to insert transition curve length for 100km/h operation, due to adjacency of turnout and consecutive curves. Transition curve length is shortened as speed limit 70km/h operation, because of express station (TCL=25m). It is necessary to coordinate with station layout plan.
					23	D-IP.23	338K883M	Left	873.21		"Exceptional case" is applied to transition curve length, due to consecutive curves (TCL=50m). It is necessary to coordinate with No.351 bridge relocation plan.
21	U-IP.21	339K625M	Left	1100	24	D-IP.24	339K537M	Left	873.21		Extension of transition curve length (UP:TCL=45m, DN:TCL=60m)
22	U-IP.22	340K092M	Right	873.21	25	D-IP.25	340K101M	Right	873.21		Extension of transition curve length (TCL=60m)
23	U-IP.23	343K521M	Left	873.21	26	D-IP.26	343K531M	Left	873.21		Extension of transition curve length (TCL=60m)
24	U-IP.24	344K632M	Right	680	27	D-IP.27	344K641M	Right	680		Extension of transition curve length (TCL=70m)
25	U-IP.25	349K392M	Right	600	28	D-IP.28	349K380M	Right	600	DN : Compound curve	UP : Extension of transition curve length (TCL=80m) DN : Integrate compound curve into one curve (R=600m, TCL=80m) It is necessary to coordinate with No.373 bridge relocation plan, both UP and DN.
					29				530	Curve in Ela sta.	
26	U-IP.26	350K056M	Left	317.53	30	D-IP.29	350K037M	Left	317.53	Close to bridge (No.373)	UP : Curve is improved within not affecting long bridge (R=350m, TCL=80m). DN : Curve is improved within not affecting long bridge (R=330m, TCL=65m). It is necessary to coordinate with No.373 bridge relocation plan, both UP and DN.

Source: JICA Study Team

Table 5.2.6 Improvement Plan of Horizontal Alignment (2 of 7)

Current Condition											Improvement Plan
UP LINE					DOWN LINE					Remarks	
No.	IP	Curve Location	Curve Direction	Radius (m)	No.	IP	Curve Location	Curve Direction	Radius (m)		
27	U-IP.27	350K442M	Left	800	31	D-IP.30	350K453M	Left	800	Close to bridge (No.374)	Integrate two consecutive curves into one curve (R=1000m,TCL=50m)
28	U-IP.28	350K628M	Left	2000	32	D-IP.31	350K640M	Left	2000		
29	U-IP.29	354K153M	Left	750	33	D-IP.32	354K166M	Left	750		Extension of transition curve length (TCL=65m)
					34	D-IP.34	363K338M	Right	437		Improved to R=900m,TCL=60m It is necessary to coordinate with No.393 bridge relocation plan.
					35	D-IP.35	363K503M	Left	437	Close to bridge (No.393)	Improved to R=1000m,TCL=50m It is necessary to coordinate with No.393 bridge relocation plan.
					36	D-IP.36	363K695M	Left	437	Close to bridge (No.393)	Improved to R=800m,TCL=60m It is necessary to coordinate with No.393 bridge relocation plan.
					37	D-IP.37	363K835M	Right	437		Improved to R=800m,TCL=60m It is necessary to coordinate with No.393 bridge relocation plan.
30	U-IP.31	365K438M	Right	480	38	D-IP.38	365K452M	Right	480		Improved to R=500m,TCL=90m
31	U-IP.32	366K348M	Left	650	39	D-IP.39	366K362M	Left	650		Extension of transition curve length (TCL=75m)
32	U-IP.33	367K158M	Right	450	40	D-IP.40	367K172M	Right	450	Bridge in curve (No.399A)	Improved to R=500m,TCL=90m
33	U-IP.34	367K575M	Left	873.21	41	D-IP.41	367K588M	Left	873.21		Extension of transition curve length (TCL=60m)
34	U-IP.35	369K397M	Right	873.21	42	D-IP.42	369K411M	Right	873.21	Close to bridge (No.405)	Improved to R=1300m,TCL=40m
35	U-IP.36	371K248M	Right	1300	43	D-IP.43	371K261M	Right	1300		Extension of transition curve length (TCL=40m)
36	U-IP.37	372K157M	Right	3000	44	D-IP.44	372K170M	Right	3000		Extension of transition curve length (TCL=20m)
37	U-IP.40	376K616M	Right	582.14	45	D-IP.47	376K628M	Right	582.14		Improved to R=800m,TCL=60m
38	U-IP.41	377K288M	Left	1000	46	D-IP.48	377K301M	Left	1000		Extension of transition curve length (TCL=50m)
39	U-IP.43	380K606M	Right	800	47	D-IP.50	380K618M	Right	800		Extension of transition curve length (TCL=60m)
40	U-IP.44	382K532M	Left	582.14	48	D-IP.51	382K543M	Left	582.14		Improved to R=600m,TCL=80m
41	U-IP.47	385K677M	Left	900	49	D-IP.54	385K689M	Left	900	Bridge in curve (No.427)	Extension of transition curve length (TCL=55m)
42	U-IP.48	386K228M	Right	700	50	D-IP.55	386K240M	Right	700		Extension of transition curve length (TCL=70m)
43	U-IP.49	387K267M	Left	800	51	D-IP.56	387K279M	Left	800	Curve in Pyokkwe sta.	Because of curved station, Improvement plan will be prepared based on topographic survey results in next surveys.
44	U-IP.50	387K530M	Left	820	52	D-IP.57	387K544M	Left	820	Curve in Pyokkwe sta.	
45	U-IP.51	388K861M	Right	873.21	53	D-IP.58	388K874M	Right	873.21		Extension of transition curve length (TCL=60m)
46	U-IP.52	390K302M	Right	800	54	D-IP.59	390K314M	Right	800	Bridge in curve (No.435)	Extension of transition curve length (TCL=60m)
47	U-IP.54	392K956M	Left	873	55	D-IP.61	392K969M	Left	873		Extension of transition curve length (TCL=60m)
48	U-IP.56	394K548M	Left	873.21	56	D-IP.63	394K562M	Left	873.21	Bridge in curve (No.441)	Extension of transition curve length (TCL=60m)
49	U-IP.57	395K002M	Right	873.21	57	D-IP.64	395K015M	Right	873.21		Extension of transition curve length (TCL=60m)
50	U-IP.59	398K025M	Right	582.14	58	D-IP.66	398K038M	Right	582.14	Close to bridge (No.448)	Extension of transition curve length (TCL=85m)
51	U-IP.60	398K541M	Left	600	59	D-IP.67	398K554M	Left	600		Extension of transition curve length (TCL=80m)
52	U-IP.61	402K856M	Left	873	60	D-IP.68	402K871M	Left	873		Extension of transition curve length (TCL=60m)
					61	D-IP.69	403K258M	Right	1000		Extension of transition curve length (TCL=50m) It is necessary to coordinate with No.453 bridge relocation plan.
					62	D-IP.70	403K411M	Left	700		Improved to R=800m,TCL=60m It is necessary to coordinate with No.453 bridge relocation plan.
					63	D-IP.71	403K723M	Left	600		Improved to R=750m,TCL=65m It is necessary to coordinate with No.453 bridge relocation plan.
					64	D-IP.72	403K882M	Right	582		Improved to R=750m,TCL=65m It is necessary to coordinate with No.453 bridge relocation plan.

Source: JICA Study Team

Table 5.2.7 Improvement Plan of Horizontal Alignment (3 of 7)

Current Condition											Improvement Plan
UP LINE					DOWN LINE					Remarks	
No.	IP	Curve Location	Curve Direction	Radius (m)	No.	IP	Curve Location	Curve Direction	Radius (m)		
53	U-IP.63	405K905M	Right	873.21	65	D-IP.74	405K923M	Right	873.21		Extension of transition curve length (TCL=60m)
54	U-IP.65	410K475M	Right	873.21	66	D-IP.76	410K491M	Right	873.21		Extension of transition curve length (TCL=60m)
55	U-IP.66	414K341M	Left	873.21	67	D-IP.77	414K357M	Left	873.21		Extension of transition curve length (TCL=60m)
56	U-IP.67	416K547M	Right	873.21	68	D-IP.78	416K563M	Right	873.21		Extension of transition curve length (TCL=60m)
57	U-IP.68	421K837M	Left	873.21	69	D-IP.79	421K852M	Left	873.21	Bridge in curve (No.480)	Extension of transition curve length (TCL=60m)
58	U-IP.69	423K762M	Left	873.21	70	D-IP.80	423K778M	Left	873.21		Extension of transition curve length (TCL=60m)
59	U-IP.70	430K353M	Left	873.21	71	D-IP.81	430K370M	Left	873.21	Close to bridge (No.497)	Extension of transition curve length (TCL=60m)
60	U-IP.71	433K447M	Right	873.21	72	D-IP.82	433K464M	Right	873.21		Extension of transition curve length (TCL=60m)
61	U-IP.72	437K760M	Right	1746.42	73	D-IP.83	437K776M	Right	1746.42		Extension of transition curve length (TCL=30m)
62	U-IP.73	441K778M	Left	582.14	74	D-IP.84	441K793M	Left	582.14		Because of station yard, Improvement plan will be prepared based on topographic survey results in next surveys.
63	U-IP.74	441K894M	Right	582	75	D-IP.85	441K854M	Right	582	Curve in Yamethin sta.	Because of station yard, Improvement plan will be prepared based on topographic survey results in next surveys.
64	U-IP.75	442K454M	Right	582	76	D-IP.86	442K023M	Left	582	Curve in Yamethin sta.	Because of station yard, Improvement plan will be prepared based on topographic survey results in next surveys.
65	U-IP.76	442K635M	Left	582						Curve in Yamethin sta.	Because of station yard, Improvement plan will be prepared based on topographic survey results in next surveys.
66	U-IP.77	442K910M	Left	873.21	77	D-IP.88	442K926M	Left	873.21	Close to Yamethin sta. Bridge in curve (No.513C)	"Exceptional case" is applied to transition curve length, due to turnout before curve (TCL=50m). It is necessary to coordinate with station layout plan.
67	U-IP.78	445K990M	Right	1100	78	D-IP.89	446K007M	Right	1100	Bridge in curve (No.514)	Extension of transition curve length (TCL=45m)
68	U-IP.79	447K436M	Left	1300	79	D-IP.90	447K453M	Left	1300	Bridge in curve (No.515A)	Extension of transition curve length (TCL=40m)
69	U-IP.80	454K079M	Right	1746.42	80	D-IP.91	454K096M	Right	1746.42	Close to Shweda sta.	Extension of transition curve length (TCL=30m) It is necessary to coordinate with station layout plan.
70	U-IP.81	457K753M	Left	582.14	81	D-IP.92	457K769M	Left	582.14		UP : Improved to R=1000m,TCL=50m DN : Improved to R=1400m,TCL=35m It is necessary to coordinate with No.527 bridge relocation plan, both UP and DN.
71	U-IP.82	457K931M	Right	582.14	82	D-IP.93	457K955M	Left	582.14		UP : Improved to R=2200m,TCL=25m DN : Improved to R=3200m,TCL=15m It is necessary to coordinate with No.527 bridge relocation plan, both UP and DN.
72	U-IP.83	458K062M	Right	582	83	D-IP.94	458K231M	Right	582		Improved to R=1500m,TCL=30m It is necessary to coordinate with No.527 bridge relocation plan.
73	U-IP.84	458K832M	Left	1310	84	D-IP.95	458K850M	Left	1310	Bridge in curve (No.527A)	Extension of transition curve length (TCL=35m)
					85	D-IP.96	459K683M	Right	500		Improved to R=1300m,TCL=40m It is necessary to coordinate with No.529 bridge relocation plan.
					86	D-IP.97	459K740M	Left	500		Improved to R=1300m,TCL=40m It is necessary to coordinate with No.529 bridge relocation plan.
					87	D-IP.98	459K877M	Left	500		Transition curve length is shortened as speed limit 90km/h operation, because of consecutive curves (R=1100m,TCL=35m). It is necessary to coordinate with No.529 bridge relocation plan.
					88	D-IP.99	459K935M	Right	500		Transition curve length is shortened as speed limit 90km/h operation, because of consecutive curves (R=1100m,TCL=35m). It is necessary to coordinate with No.529 bridge relocation plan.
74	U-IP.85	460K363M	Right	436.6	89	D-IP.100	460K380M	Right	436.6		Improved to R=500m,TCL=90m
					90	D-IP.101	462K185M	Right	582.14		Improved to R=1200m,TCL=40m
					91	D-IP.102	462K297M	Left	582.14	Close to bridge (No.531)	Improved to R=1200m,TCL=40m
					92	D-IP.103	462K383M	Left	582.14	Close to bridge (No.531)	It is difficult to insert transition curve length for 100km/h operation, due to adjacency of bridge and turnout. Transition curve length is shortened as speed limit 70km/h operation, because of express station (R=620m,TCL=30m). It is necessary to coordinate with station layout plan.
					93	D-IP.104	462K523M	Right	582.14		Because of station yard, Improvement plan will be prepared based on topographic survey results in next surveys.
75	U-IP.86	462K454M	Left	582						Curve incidental to turnout	Because of station yard, Improvement plan will be prepared based on topographic survey results in next surveys.
76	U-IP.88	462K659M	Right	500	94	D-IP.105	462K674M	Right	500	Curve in Pyawbwe sta.	Because of station yard, Improvement plan will be prepared based on topographic survey results in next surveys.

Source: JICA Study Team

Table 5.2.8 Improvement Plan of Horizontal Alignment (4 of 7)

Current Condition											Improvement Plan
UP LINE					DOWN LINE					Remarks	
No.	IP	Curve Location	Curve Direction	Radius (m)	No.	IP	Curve Location	Curve Direction	Radius (m)		
77	U-IP.89	463K702M	Right	1100	95	D-IP.106	463K714M	Right	1100	Bridge in curve (No.532)	Extension of transition curve length (TCL=45m) It is necessary to coordinate with station layout plan.
78	U-IP.90	464K955M	Left	1300	96	D-IP.107	464K967M	Left	1300	Bridge in curve (No.533, 534)	Extension of transition curve length (TCL=40m)
79	U-IP.91	468K755M	Left	2800	97	D-IP.108	468K769M	Left	2800	Bridge in curve (No.545, 546)	Extension of transition curve length (TCL=20m)
80	U-IP.92	470K006M	Left	2500	98	D-IP.109	470K022M	Left	2500	Bridge in curve (No.548, 549)	Extension of transition curve length (TCL=20m)
81	U-IP.93	478K396M	Right	1746.42	99	D-IP.110	478K412M	Right	1746.42	Bridge in curve (No.570)	Extension of transition curve length (TCL=30m)
82	U-IP.94	480K549M	Left	3493							Extension of transition curve length (TCL=15m) It is necessary to coordinate with No.574 bridge relocation plan.
83	U-IP.95	480K756M	Right	3493						Close to bridge (No.574)	Extension of transition curve length (TCL=15m) It is necessary to coordinate with No.574 bridge relocation plan.
84	U-IP.96	481K015M	Right	3493							Extension of transition curve length (TCL=15m) It is necessary to coordinate with No.574 bridge relocation plan.
85	U-IP.97	481K220M	Left	3493							Extension of transition curve length (TCL=15m) It is necessary to coordinate with No.574 bridge relocation plan.
86	U-IP.98	483K459M	Left	436.6							Improved to R=1000m,TCL=50m It is necessary to coordinate with No.581 bridge relocation plan.
87	U-IP.99	483K674M	Right	436.6							Improved to R=900m,TCL=55m It is necessary to coordinate with No.581 bridge relocation plan.
88	U-IP.100	483K871M	Right	436.6							Improved to R=2000m,TCL=30m It is necessary to coordinate with No.581 bridge relocation plan.
89	U-IP.101	483K989M	Left	436.6							Improved to R=3200m,TCL=15m It is necessary to coordinate with No.581 bridge relocation plan.
90	U-IP.102	484K242M	Right	1746.42	100	D-IP.114	484K256M	Right	1746.42	Bridge in curve (No.582)	Extension of transition curve length (TCL=30m)
91	U-IP.103	485K661M	Left	436.6							Improved to R=1600m,TCL=30m It is necessary to coordinate with No.585 bridge relocation plan.
92	U-IP.104	485K800M	Right	436.6						Close to bridge (No.585)	Improved to R=1000m,TCL=50m It is necessary to coordinate with No.585 and 586 bridge relocation plan.
93	U-IP.105	485K861M	Left	436.6							Improved to R=1400m,TCL=35m It is necessary to coordinate with No.585 and 586 bridge relocation plan.
94	U-IP.107	487K756M	Left	1746.42							Extension of transition curve length (TCL=30m) It is necessary to coordinate with No.588 bridge relocation plan.
95	U-IP.108	488K069M	Right	1746.42						Bridge in curve (No.588)	Extension of transition curve length (TCL=30m) It is necessary to coordinate with No.588 bridge relocation plan.
96	U-IP.109	488K232M	Left	1746.42						Bridge in curve (No.589A)	Extension of transition curve length (TCL=30m) It is necessary to coordinate with No.588 bridge relocation plan.
97	U-IP.110	489K817M	Left	2000	101	D-IP.120	489K829M	Left	2000		Extension of transition curve length (TCL=30m)
98	U-IP.111	490K704M	Right	2000	102	D-IP.121	490K717M	Right	2000		Extension of transition curve length (TCL=30m)
99	U-IP.115	492K678M	Left	500						Curve in Thazi sta.	Because of station yard, Improvement plan will be prepared based on topographic survey results in next surveys.
100	U-IP.116	492K891M	Right	500						Curve in Thazi sta.	Because of station yard, Improvement plan will be prepared based on topographic survey results in next surveys.
101	U-IP.117	493K209M	Right	500						Curve in Thazi sta.	Because of station yard, Improvement plan will be prepared based on topographic survey results in next surveys.
102	U-IP.118	493K420M	Left	500						Curve in Thazi sta.	Because of station yard, Improvement plan will be prepared based on topographic survey results in next surveys.
103	U-IP.119	495K381M	Left	1746.42	103	D-IP.126	495K392M	Left	1746.42	Bridge in curve (No.605)	Extension of transition curve length (TCL=30m)
104	U-IP.122	509K314M	Right	1600	104	D-IP.129	509K326M	Right	1600		Extension of transition curve length (TCL=30m)

Source: JICA Study Team

Table 5.2.9 Improvement Plan of Horizontal Alignment (5 of 7)

Current Condition											Improvement Plan
UP LINE					DOWN LINE					Remarks	
No.	IP	Curve Location	Curve Direction	Radius (m)	No.	IP	Curve Location	Curve Direction	Radius (m)		
105	U-IP.124	519K422M	Left	1000	105	D-IP.131	519K433M	Left	1000		Transition curve length is shortened as speed limit 70km/h operation, because of express station (TCL=15m) It is necessary to coordinate with station layout plan.
106	U-IP.125	520K037M	Right	873.21	106	D-IP.132	520K048M	Right	873.21		Extension of transition curve length (TCL=60m)
					107	D-IP.133	522K335M	Right	436.6		Improved to R=1000m,TCL=50m
					108	D-IP.134	522K448M	Left	436.6		Improved to R=1000m,TCL=50m
					109	D-IP.135	522K595M	Left	436.6		Improved to R=1000m,TCL=50m
					110	D-IP.136	522K681M	Right	436.6		Improved to R=1000m,TCL=50m
107	U-IP.126	524K470M	Left	873.21	111	D-IP.137	524K482M	Left	873.21		Extension of transition curve length (TCL=60m)
108	U-IP.127	526K299M	Left	436.6	112	D-IP.138	526K342M	Left	436.6		Improved to R=600m,TCL=80m
109	U-IP.128	526K804M	Right	436.6	113	D-IP.139	526K846M	Right	436.6		Improved to R=600m,TCL=80m
110	U-IP.129	529K399M	Right	1800	114	D-IP.140	529K410M	Right	1800		Extension of transition curve length (TCL=30m)
111	U-IP.130	531K485M	Left	436.6						Close to bridge (No.682)	Improved to R=1400m,TCL=35m It is necessary to coordinate with No.683 bridge relocation plan.
112	U-IP.131	531K561M	Right	436.6							Improved to R=1600m,TCL=30m It is necessary to coordinate with No.683 bridge relocation plan.
113	U-IP.133	532K662M	Left	873.21	115	D-IP.141	532K678M	Left	873.21		"Exceptional case" is applied to transition curve length, due to bridge after curve (TCL=50m). It is necessary to coordinate with No.684 bridge relocation plan.
114	U-IP.134	532K952M	Left	873.21	116	D-IP.142	532K926M	Left	1000		Extension of transition curve length (UP:TCL=60m, DN:TCL=50m) It is necessary to coordinate with No.684 bridge relocation plan, both UP and DN.
115	U-IP.135	534K842M	Right	436.6	117	D-IP.143	534K814M	Right	436.6		Improved to R=600m,TCL=80m
116	U-IP.136	535K050M	Right	436.6	118	D-IP.144	535K095M	Right	436.6	Close to bridge (No.688)	UP : Only insertion of transition curve, due to consecutive curves (TCL=70m, "Exceptional case" is applied) DN : Improved to R=500m,TCL=80m. "Exceptional case" is applied to transition curve length, due to adjacency of bridge.
117	U-IP.137	536K427M	Left	436.6							Improved to R=700m,TCL=70m It is necessary to coordinate with No.691 bridge relocation plan.
118	U-IP.138	536K619M	Right	436.6							Improved to R=700m,TCL=70m It is necessary to coordinate with No.691 bridge relocation plan.
119	U-IP.139	537K045M	Right	436.6							Improved to R=700m,TCL=70m It is necessary to coordinate with No.691 bridge relocation plan.
120	U-IP.140	537K237M	Left	436.6							Improved to R=700m,TCL=70m It is necessary to coordinate with No.691 bridge relocation plan.
121	U-IP.141	538K807M	Right	1746.42	119	D-IP.147	538K813M	Right	1746.42		Extension of transition curve length (TCL=30m)
122	U-IP.142	541K554M	Left	800	120	D-IP.148	541K561M	Left	800		Extension of transition curve length (TCL=60m)
123	U-IP.143	543K712M	Right	1200	121	D-IP.149	543K720M	Right	1200		Extension of transition curve length (TCL=40m)
124	U-IP.144	547K868M	Left	1600							Extension of transition curve length (TCL=30m) It is necessary to coordinate with No.699 bridge relocation plan.
					122	D-IP.150	548K069M	Left	600		Improved to R=900m,TCL=45m. "Exceptional case" is applied to transition curve length, due to consecutive curves. It is necessary to coordinate with No.699 bridge relocation plan.
					123	D-IP.151	548K220M	Left	873.21		Extension of transition curve length (TCL=50m). "Exceptional case" is applied to transition curve length, due to consecutive curves. It is necessary to coordinate with No.699 bridge relocation plan.

Source: JICA Study Team

Table 5.2.10 Improvement Plan of Horizontal Alignment (6 of 7)

Current Condition											Improvement Plan
UP LINE					DOWN LINE					Remarks	
No.	IP	Curve Location	Curve Direction	Radius (m)	No.	IP	Curve Location	Curve Direction	Radius (m)		
125	U-IP.145	548K574M	Left	1100	124	D-IP.152	548K509M	Left	700		Extension of transition curve length (UP:TCL=45m, DN:TCL=70m) It is necessary to coordinate with No.699 bridge relocation plan.
126	U-IP.146	549K248M	Right	582.14	125	D-IP.153	549K271M	Right	582.14		Extension of transition curve length (TCL=85m)
					126	D-IP.154	556K922M	Right	2000		Improved to R=3000m,TCL=20m It is necessary to coordinate with No.718 bridge relocation plan.
					127	D-IP.155	557K074M	Left	2000		Improved to R=3000m,TCL=20m It is necessary to coordinate with No.718 bridge relocation plan.
					128	D-IP.156	557K374M	Left	2000		Improved to R=3200m,TCL=15m It is necessary to coordinate with No.718 bridge relocation plan.
					129	D-IP.157	557K597M	Right	2000		Improved to R=3200m,TCL=15m It is necessary to coordinate with No.718 bridge relocation plan.
127	U-IP.147	557K839M	Right	436.6	130	D-IP.158	557K860M	Right	436.6	DN : Compound curve	UP : Improved to R=500m,TCL=90m, DN : Integrate three consecutive curves into one curve (R=500m, TCL=90m) It is necessary to coordinate with No.719 bridge relocation plan, both UP and DN.
					131				350		
					132	D-IP.159	558K078M	Left	437		
					133	D-IP.160	558K277M	Left	437	Close to bridge (No.719)	Improved to R=800m,TCL=60m It is necessary to coordinate with No.719 bridge relocation plan.
					134	D-IP.161	558K436M	Right	437		Improved to R=800m,TCL=60m It is necessary to coordinate with No.719 bridge relocation plan.
128	U-IP.149	559K060M	(Left curve)	780	135	D-IP.162	559K080M	Left	780	Bridge in curve (No.720, 720A) Curve in Myittha sta.	Extension of transition curve length (TCL=60m)。 It is necessary to coordinate with station layout plan.
					136	D-IP.164	566K600M	Right	500		Improved to R=2000m,TCL=30m It is necessary to coordinate with No.730 bridge relocation plan.
					137	D-IP.165	566K656M	Left	500		Improved to R=2000m,TCL=30m It is necessary to coordinate with No.730 bridge relocation plan.
129	U-IP.151	566K812M	Right	873.21	138	D-IP.166	566K833M	Right	873.21		Extension of transition curve length (TCL=60m) It is necessary to coordinate with No.730 bridge relocation plan.
130	U-IP.152	567K586M	Left	873.21	139	D-IP.167	567K608M	Left	873.21	Close to bridge (No.731)	Extension of transition curve length (TCL=60m)
131	U-IP.155	576K676M	Right	873.21	140	D-IP.170	576K697M	Right	873.21	Bridge in curve (No.745)	Extension of transition curve length (TCL=60m)
132	U-IP.156	577K104M	Left	873.21	141	D-IP.171	577K125M	Left	873.21		Extension of transition curve length (TCL=60m)
133	U-IP.157	577K654M	Left	436.6							Improved to R=3000m,TCL=20m It is necessary to coordinate with No.748 bridge relocation plan.
134	U-IP.158	577K894M	Right	436.6							Improved to R=2600m,TCL=20m It is necessary to coordinate with No.748 bridge relocation plan.
135	U-IP.159	578K045M	Right	436.6							Improved to R=2000m,TCL=30m It is necessary to coordinate with No.748 bridge relocation plan.
136	U-IP.160	578K221M	Left	436.6	142	D-IP.173	578K243M	Left	436.6		Only insertion of transition curve, due to many houses continuously along railway (TCL=40m). Transition curve length is shortened as speed limit 70km/h operation, because of consecutive curves and express station.
137	U-IP.161	578K435M	Right	582.14	143	D-IP.174	578K459M	Right	582.14	Close to Kyaukse sta.	Only insertion of transition curve, due to many houses continuously along railway (TCL=30m). Transition curve length is shortened as speed limit 70km/h operation, because of consecutive curves and express station. It is necessary to coordinate with station layout plan.
138	U-IP.163	583K393M	Right	873.21	144	D-IP.176	583K416M	Right	873.21		Improved to R=1100m,TCL=45m
139	U-IP.164	587K909M	Left	1746.42	145	D-IP.177	587K932M	Left	1746.42		Extension of transition curve length (TCL=30m)
140	U-IP.165	589K634M	Left	450	146	D-IP.178	589K659M	Left	450		Improved to R=500m,TCL=90m

Source: JICA Study Team

Table 5.2.11 Improvement Plan of Horizontal Alignment (7 of 7)

Current Condition											Improvement Plan
UP LINE					DOWN LINE					Remarks	
No.	IP	Curve Location	Curve Direction	Radius (m)	No.	IP	Curve Location	Curve Direction	Radius (m)		
141	U-IP.166	590K764M	Right	436.6	147	D-IP.179	590K790M	Right	436.6	Close to bridge (No.792)	Improved to R=500m,TCL=90m
142	U-IP.169	599K596M	Right	700	148	D-IP.182	599K620M	Right	700	Close to bridge (No.816)	Extension of transition curve length (TCL=70m)
143	U-IP.170	599K907M	Left	1746.42	149	D-IP.183	599K930M	Left	1746.42		Extension of transition curve length (TCL=30m)
144	U-IP.171	601K593M	Right	873.21	150	D-IP.184	601K616M	Right	873.21	Close to bridge (No.820)	Extension of transition curve length (TCL=60m)
145	U-IP.172	602K397M	Left	873.21	151	D-IP.185	602K421M	Left	873.21		Extension of transition curve length (TCL=60m)
146	U-IP.173	603K817M	Right	1746	152	D-IP.186	603K839M	Right	1746	Curve in Paleik sta. Bridge in curve (No.824)	Extension of transition curve length (TCL=30m) It is necessary to coordinate with station layout plan.
147	U-IP.174	605K516M	Left	582.14	153	D-IP.187	605K537M	Left	582.14		Improved to R=700m,TCL=70m
148	U-IP.175	606K363M	Right	349.28	154	D-IP.188	606K361M	Right	300		UP : Only insertion of transition curve in order to prevent curve from affecting long bridge. Transition curve length is shortened as speed limit 40km/h operation (TCL=10m). DN : Only insertion of transition curve in order to prevent curve from affecting long bridge (TCL=70m). It is necessary to coordinate with No.826 bridge relocation plan, both UP and DN.
					155	D-IP.189	606K788M	Left	700	Close to bridge (No.826)	UP : Extension of transition curve length (TCL=90m)
149	U-IP.176	606K934M	Left	550	156	D-IP.190	606K996M	Left	550		DN : Integrate two consecutive curves into one curve (R=650m, TCL=75m). It is necessary to coordinate with No.826 bridge relocation plan, both UP and DN.
150	U-IP.177	608K689M	Left	873.21	157	D-IP.191	608K708M	Left	873.21	Curve in Myitnge sta.	Extension of transition curve length (TCL=60m) It is necessary to coordinate with station layout plan.
151	U-IP.179	612K272M	Right	436.6	158	D-IP.193	612K291M	Right	436.6		Improved to R=500m,TCL=90m
					159	D-IP.194	612K473M	Right	2000		Improved to R=3200m,TCL=15m It is necessary to coordinate with No.830 bridge relocation plan.
152	U-IP.181	613K189M	Left	436.6	160	D-IP.196	613K202M	Left	436.6		Improved to R=500m,TCL=90m It is necessary to coordinate with No.830 bridge relocation plan.
153	U-IP.182	613K821M	Left	436.6	161	D-IP.197	613K842M	Left	436.6	Bridge in curve (No.832)	Improved to R=500m,TCL=90m
154	U-IP.183	614K431M	Right	436.6	162	D-IP.198	614K453M	Right	436.6		Improved to R=500m,TCL=90m
155	U-IP.184	616K017M	Right	582.14	163	D-IP.199	616K037M	Right	582.14		Improved to R=800m,TCL=60m
156	U-IP.185	618K059M	Right	582.14	164	D-IP.200	618K079M	Right	582.14		Improved to R=600m,TCL=80m
157	U-IP.186	619K412M	Left	873.21	165	D-IP.201	619K431M	Left	873.21		Extension of transition curve length (TCL=60m)
158	U-IP.187	621K195M	Right	300	166	D-IP.202	621K214M	Right	300	Curve in Mandalay sta.	Not improved because of curve in station yard
159	U-IP.188	621K400M	Left	300	167	D-IP.203	621K419M	Left	300	Curve in Mandalay sta.	Not improved because of curve in station yard

Source: JICA Study Team

3) Curve with Speed Limit

Although enlargement of curve radius and extension of transition curve length are examined in this survey so that 100-km/h operation of DEMU is achieved, there are cases where it is impossible to improve the curves sufficiently due to the topographical reason along the railway and two close curves. As for such a curve, speed limit is set unavoidably, and the efficient and realistic plan is examined without land acquisitions and big impact on environmental social consideration.

The curves with speed limit for DEMU are shown in Table 5.2.12.

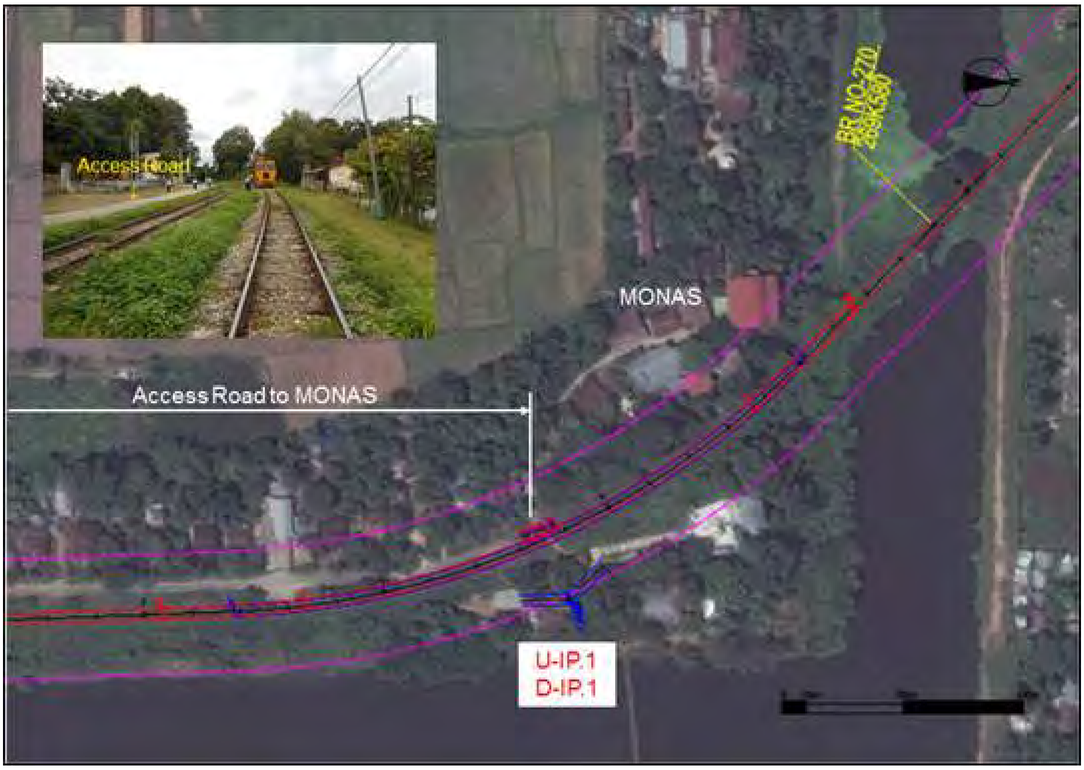
Table 5.2.12 Curves with Speed Limit for DEMU

No.	Current Condition	Improvement Plan	Limit Speed (DEMU)
i	U-IP.1 R=349.28m D-IP.1 R=349.28m	R=349.28m, TCL=60m R=349.28m, TCL=60m	75km/h
ii	D-IP.22 R=750m	R=750m, TCL=25m	70km/h
iii	U-IP.26 R=317.53m D-IP.29 R=317.53m	R=350m, TCL=80m R=330m, TCL=65m	85km/h 75km/h
iv	D-IP.98 R=500m	R=1100m, TCL=35m	90km/h
v	D-IP.99 R=500m	R=1100m, TCL=35m	90km/h
vi	D-IP.103 R=582.14m	R=620m, TCL=30m	70km/h
vii	U-IP.124 R=1000m D-IP.131 R=1000m	R=1000m, TCL=15m R=1000m, TCL=15m	70km/h
viii	U-IP.136 R=436.6m	R=436.6m, TCL=70m	90km/h
ix	U-IP.160 R=436.6m D-IP.173 R=436.6m	R=436.6m, TCL=40m R=436.6m, TCL=40m	70km/h
x	U-IP.161 R=582.14m D-IP.174 R=582.14m	R=582.14m, TCL=30m R=582.14m, TCL=30m	70km/h
xi	U-IP.175 R=349.28m D-IP.188 R=300m	R=349.28m, TCL=10m R=300m, TCL=70m	40km/h 75km/h

Source: JICA Study Team

i) U-IP.1, D-IP.1

Although the existing radius is R=349.28m for both Up and Down Lines, there is an access road to Monas on the west side of the railway, and improving the curve radius will interfere with this access road. Therefore, only the extension of the transition curve length is done in this section, and the limit speed is 75km/h because of the radius 349.28m.



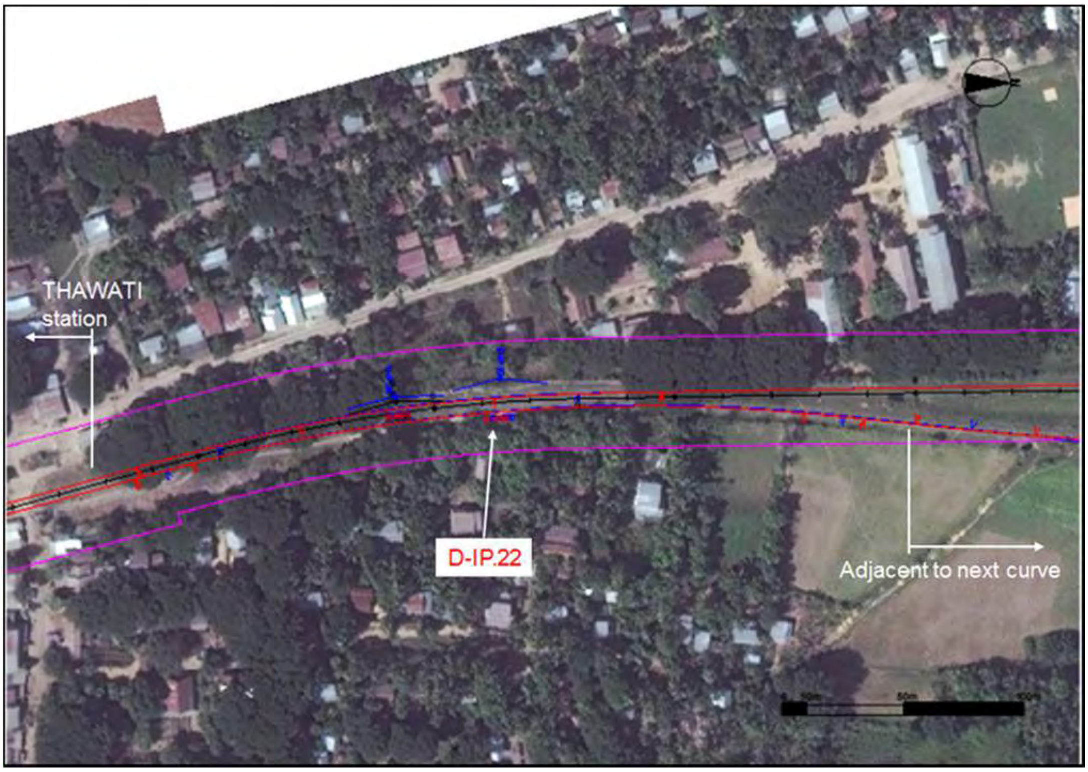
Source: JICA Study Team

Figure 5.2.3 Curve Improvement of U-IP.1, D-IP.1

ii) D-IP.22

Although the existing radius is R=750m and the transition curve length is extended, it is difficult to insert the transition curve for 100km/h operation (TCL=65m) due to adjacency of turnout in Thawati station before curve and consecutive curves after curve. Thawati station is the express station where all trains stop, so the design speed before and after station is reduced to 70km/h, and the transition curve length is shortened.

In order to decide the curve improvement plan, it is necessary to coordinate with the station layout plan of Thawati station.



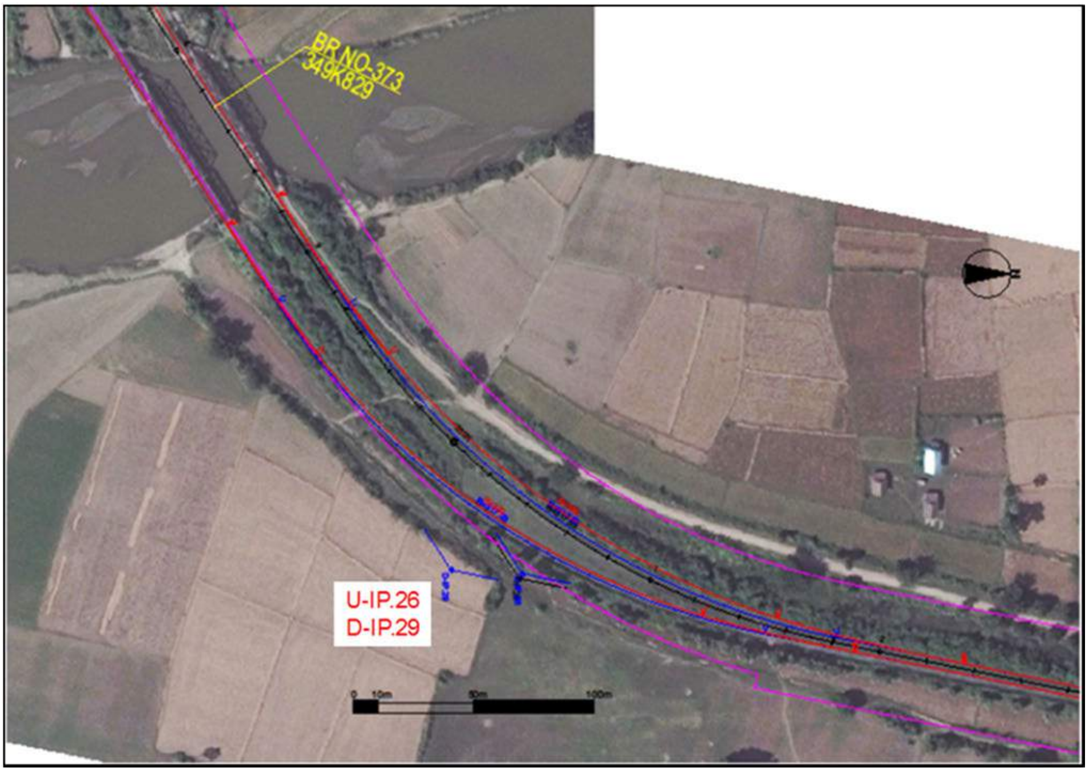
Source: JICA Study Team

Figure 5.2.4 Curve Improvement of D-IP.22

iii) U-IP.26, D-IP.29

Although the existing radius is R=317.53m for both Up and Down Lines, there is the No.373 bridge before curve, improving the radius to 500m will affect the bridge. Therefore, the improvements are done so that the curve does not affect the bridge in this section. Curve radius is improved to R=350m for Up Line and R=330m for Down Line. The limit speed is 85km/h for Up Line and 75km/h for Down Line because of the curve radius.

There is a No.373 bridge relocation plan, in order to decide the curve improvement plan, it is necessary to coordinate with the bridge relocation plan.



Source: JICA Study Team

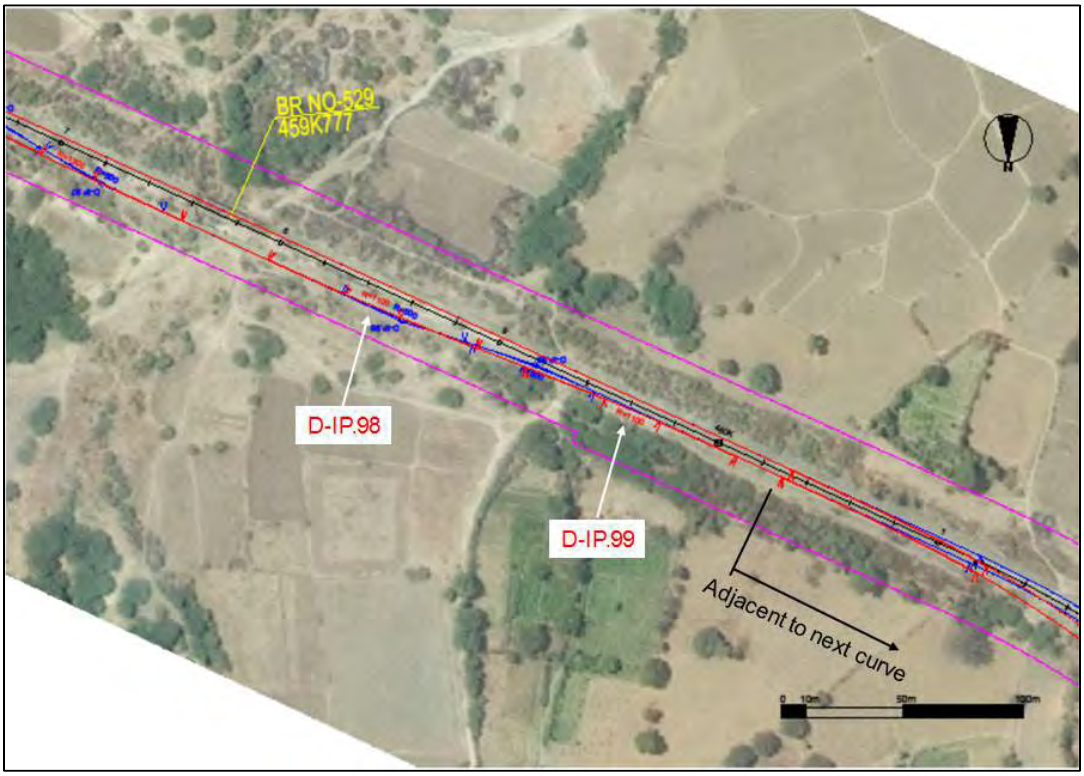
Figure 5.2.5 Curve Improvement of U-IP.26, D-IP.29

iv) D-IP.98, v) D-IP.99

D-IP.98 and D-IP.99 are S-curve (radius 500m) between No.529 bridge before curve and the next curve. In this section there are restrictions before and after curve, and it is difficult to secure specified transition curve length. Therefore the design speed is reduced to 90km/h, and the transition curve length is shortened.

Also, since the circular curve length becomes less than one vehicle length (20m) due to the extension of the transition curve, the radius is improved to 1100m to secure the specified circular curve length.

There is a No.529 bridge relocation plan, in order to decide the curve improvement plan, it is necessary to coordinate with the bridge relocation plan.



Source: JICA Study Team

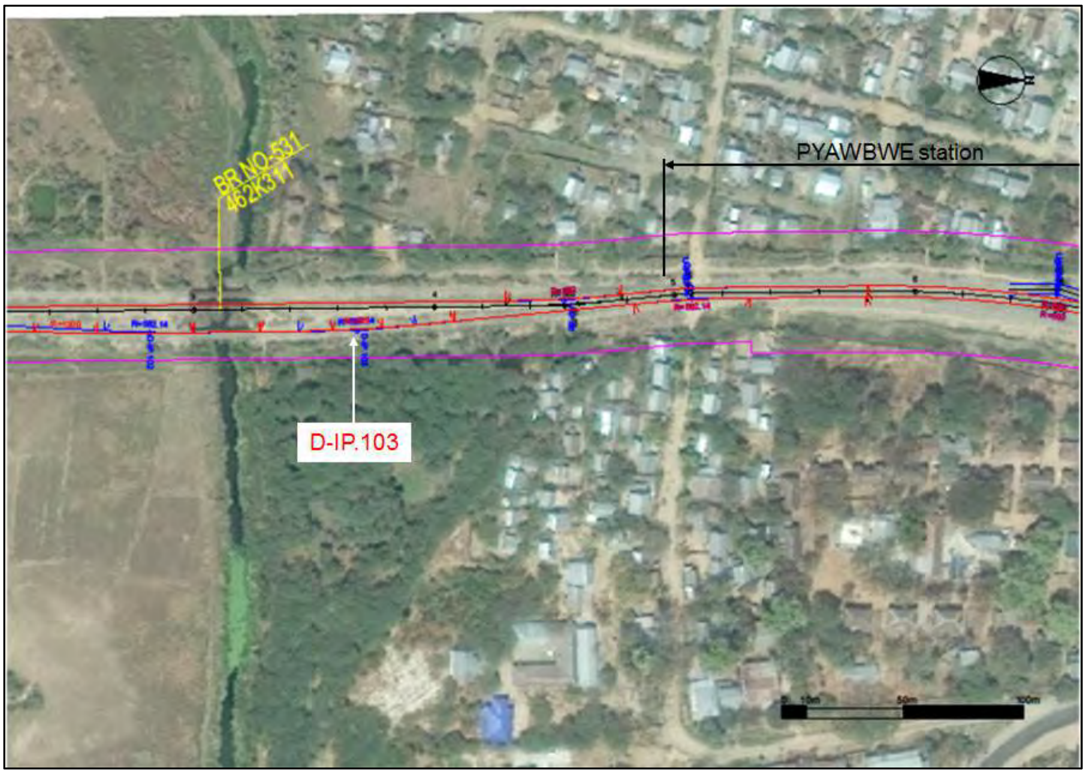
Figure 5.2.6 Curve Improvement of D-IP.98, D-IP.99

vi) D-IP.103

Before D-IP.103, No.531 bridge and curve are close to the curve, and after D-IP.103, the turnout of Pyawbwe station is close to the curve. Therefore, it is difficult to secure specified transition curve length in this section. Pyawbwe station is the express station where all trains stop, so the design speed before and after station is reduced to 70km/h, and the transition curve length is shortened.

Although the existing curve radius is 582.14m, since the circular curve length becomes less than one vehicle length (20m) due to the insertion of the transition curve, the radius is improved to 620m to secure the specified circular curve length.

In order to decide the curve improvement plan, it is necessary to coordinate with the station layout plan of Pyawbwe station.



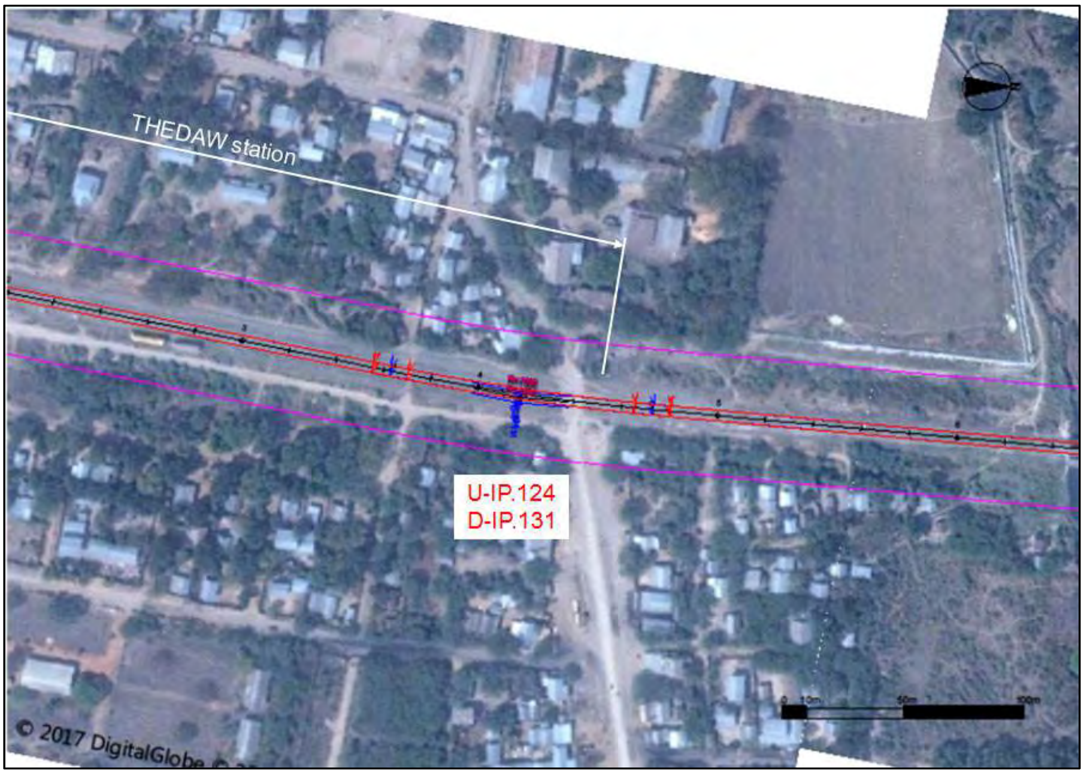
Source: JICA Study Team

Figure 5.2.7 Curve Improvement of D-IP.103

vii) U-IP.124, D-IP.131

The curve is located in Thedaw station yard, and the turnout will be arranged near this curve in the station layout plan. Considering that the turnout is arranged near this curve, in order to make the curve length as short as possible, the design speed is reduced to 70km/h, and the transition curve length is shortened (Thedaw station is the express station where all trains stop).

In order to decide the curve improvement plan, it is necessary to coordinate with the station layout plan of Thedaw station.



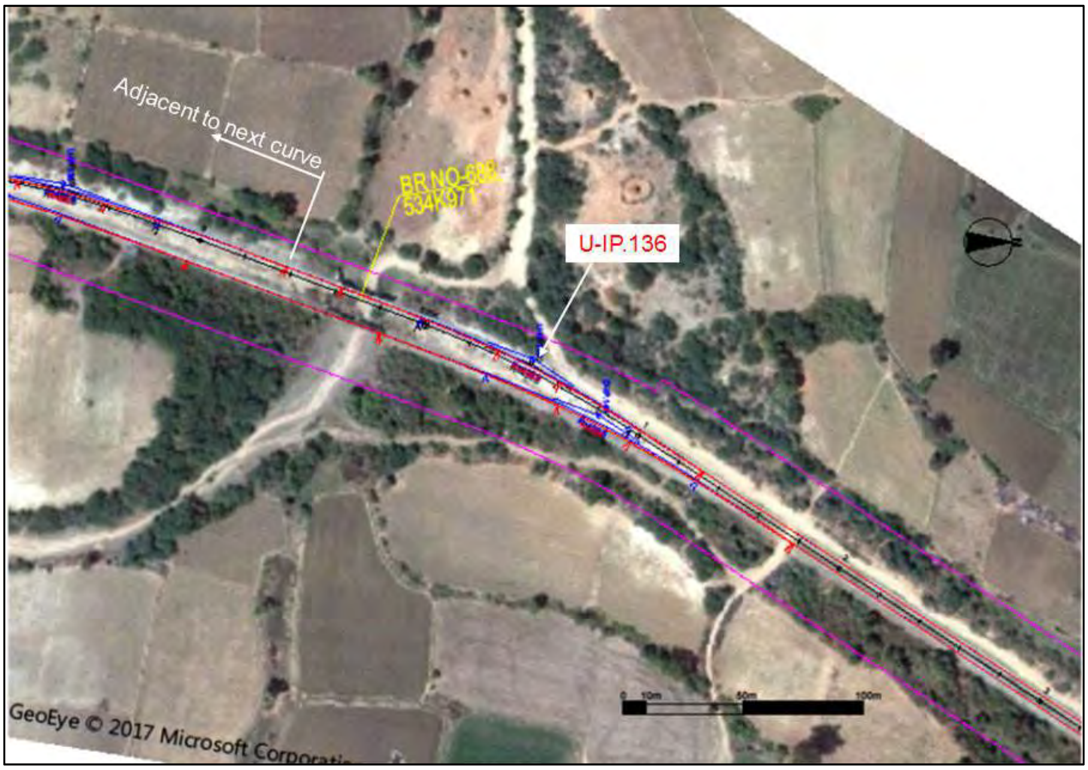
Source: JICA Study Team

Figure 5.2.8 Curve Improvement of U-IP.124, D-IP.131

viii) U-IP.136

Although the existing radius is 436.6m, it is difficult to improve the curve radius to 500m because the another curve is close to U-IP.136. Therefore, only the extension of the transition curve length is done in this section (regarding the transition curve length, TCL=70m in exceptional case is applied), and the limit speed is 90km/h because of the radius 436.6m.

Although the transition curve interfere with the No.688 bridge due to the curve improvement, the No.688 bridge is planned to be rebuilt into a box culvert or a hume pipe and there is no problem even if the curve is placed on the bridge.



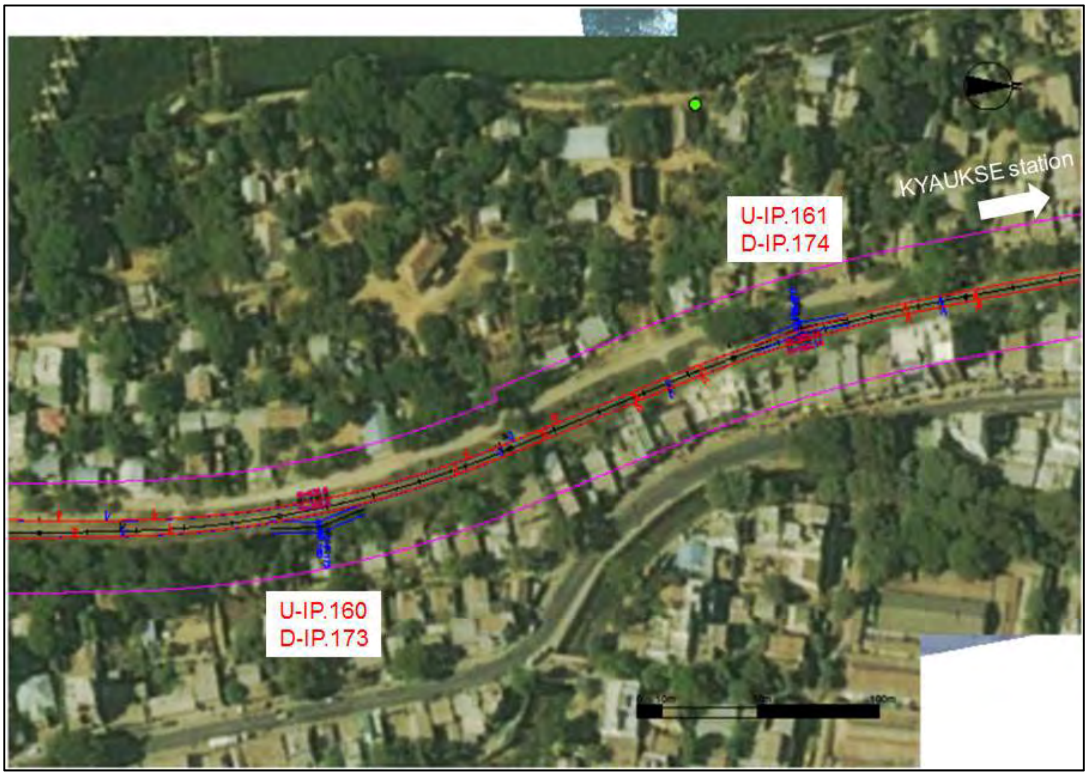
Source: JICA Study Team

Figure 5.2.9 Curve Improvement of U-IP.136

ix) U-IP.160, D-IP.173 x) U-IP.161, D-IP.174

The curve is S-curve with R=436.6m and R=582.14 m. Also there is Kyaukse station after curve. Since the road is parallel to the west side of the railway and the many houses continuously are located on the east side of the railway, improvement of the curve radius is not done and only the transition curve is extended. As for the transition curve length, since the curve is continuous in the S-curve, Kyaukse station which is the express station is close, the design speed is reduced to 70km/h, and the transition curve length is shortened.

In order to decide the curve improvement plan, it is necessary to coordinate with the station layout plan of Kyaukse station.



Source: JICA Study Team

Figure 5.2.10 Curve Improvement of U-IP.160, D-IP.173, U-IP.161, D-IP.174

xi) U-IP.175, D-IP.188

Although the curve radius is R=349.28m for Up Line and R=300m for Down Line, No.826 bridge is close to these curves at the end point of the curves, only insertion of the transition curve is done without improvement of the curve radius.

The curve of the Up Line is close to the bridge and there is almost no straight line length enough to insert the transition curve. Therefore, the transition curve can be inserted only 10m-length and it is necessary to set the speed limit of 40km/h.

The transition curve of TCL=70m can be inserted for the Down Line, and the speed limit is 75km/h because of the curve radius of 300m.

There is a No.826 bridge relocation plan, in order to decide the curve improvement plan, it is necessary to coordinate with the bridge relocation plan.

Source: JICA Study Team

Figure 5.2.11 Curve Improvement of U-IP.175, D-IP.188

4) Improvement of horizontal alignment before and after bridge, related to bridge relocation plan

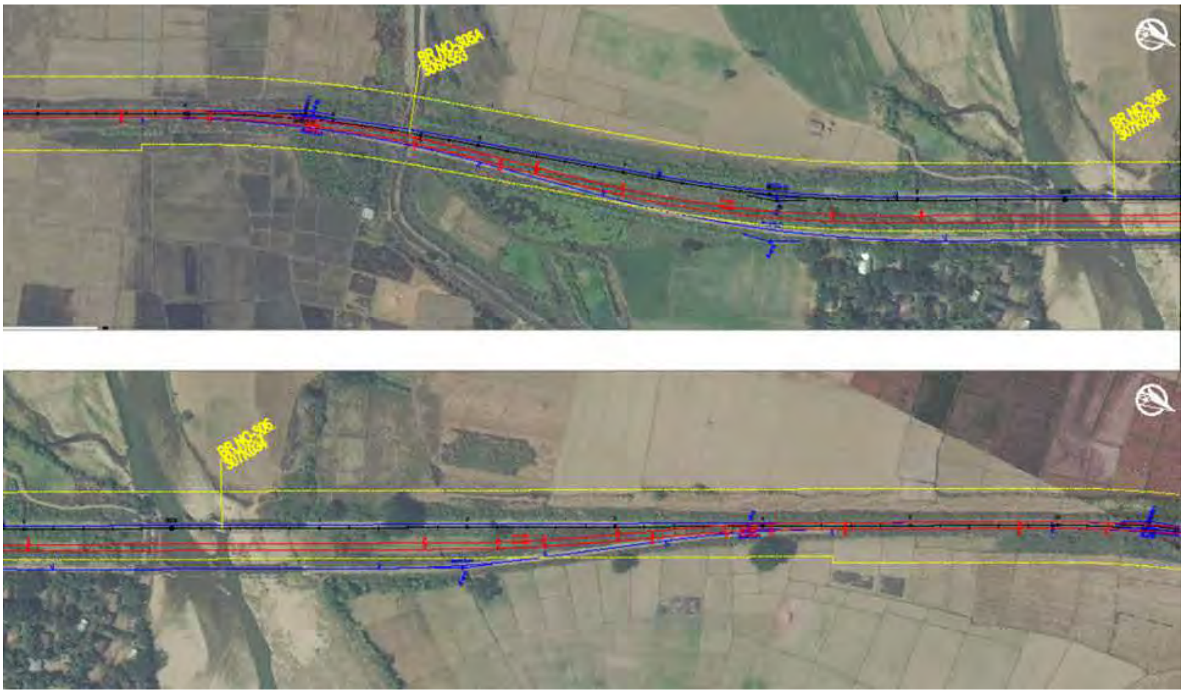
In this survey, as for the alignment near the bridge, the alignment improvement plans are studied assuming that the bridge is in the current position. However, in the bridge improvement plan, improvement policies for all the bridges are studied, and the bridge relocation position is proposed for 27 bridges shown in Table 5.2.13. In this survey, as a reference, the alignment improvement plan is studied for all 27 bridges before and after the bridge in accordance with the bridge relocation position as shown in Figure 5.2.12.

In the bridge improvement plan, site survey and soundness survey will be conducted for all existing bridges at the detailed design stage, and improvements such as relocation and repair will be finally judged. Therefore, the alignment improvement before and after the bridge will be also reexamined at the detailed design stage.

Table 5.2.13 List of Bridges to be relocated

Bridge No.	Bridge Length	Bridge No.	Bridge Length
No.306	106.07m	No.684	48.77m
No.351	54.86m	No.691	UP 105.16m, DN 85.34m
No.373	76.20m	No.692	30.48m
No.393	UP 115.82m, DN 126.19m	No.699	UP 52.58m, DN 60.96m
No.453	UP 121.92m, DN 105.16m	No.718	30.48m
No.519	34.14m	No.719	UP 91.44m, DN 95.10m
No.527	48.77m	No.730	UP 30.48m, DN 24.38m
No.529	UP 30.48m, DN 24.38m	No.739	30.48m
No.574	60.96m	No.748	70.10m
No.581	UP 34.90m, DN 36.58m	No.788	24.38m
No.585	30.48m	No.796	18.29m
No.586	36.58m	No.826	207.26m
No.588	UP 36.58m, DN 48.77m	No.830	97.54m
No.683	70.10m	-	-

Source: JICA Study Team



Source: JICA Study Team

Figure 5.2.12 Alignment Improvement before and after bridge related to bridge relocation plan (Example of Bridge No.306)

5.3 Track and Roadbed

5.3.1 Current Condition of Track and Roadbed

(1) Specifications of Track Structure of Myanma Railway

The major specifications of Myanma Railways are shown in Table 5.3.1.

Table 5.3.1 Specifications of Track Structure of Myanma Railway

Item			Contents	Comment
Standard Gauge			1,000mm	
Maximum Lord			17.0 ton (12.5 ton)	
Minimum Curve Radius			R=291m	
Maximum Gradient			10‰	2,5‰ Station Yard and Storage Track
Structure Gauge	Height		3,808 mm	
	Width		3,810 mm	
Vehicle Gauge	Coach	Height	3,505 mm	
		Width	2,819 mm	
	Freight Wagon	Height	3,429 mm	
		Width	2,591 mm	
Width of Formation	Single Track		6,096 mm	
	Double Track		9,906 mm	
Turnout			1:12 1:8.5	

Source: JICA Study Team

(2) Current Condition of Roadbed

As shown in Figure 5.3.1, the roadbed seems to have been washed out some time ago or not to have been fixed correctly in the construction stage along almost all of the track structure. For establishing a revitalization program of the roadbed, it is necessary to execute a sampling trial boring investigation on major points along the route.

Source: JICA Study Team

Figure 5.3.1 Current Condition of Roadbed and Ballast

(3) Current Condition of Ballast

There are serious problems in the condition of ballast in both the quantity and quality in almost all sections of the route. As shown in Figure 5.3.1, both heads of the sleepers are not covered by ballast, which means that the resistance force of the rail and sleeper structure is not enough against the lateral force of trains, and irregularity of alignment is easy to occur. It is also difficult to secure higher speed train operation. Therefore, to make the cut section of ballast structure to the standard design, it is necessary to supplement a greater quantity of ballast on almost all of the track structure between Taungoo and Mandalay. The quantity is estimated as approximately 500,000 m^3. According to an MR executive, they can secure both the production capacity and the transportation capacity of such a huge quantity of the ballast.

About the quality, there are two points to be improved. One is in the quality of the rock for ballast stones. The lithologic character of the rock for the ballast seems to be in lamellar structure, and the surface of ballast stones is relatively flat. It is considered that the frictional force between the ballast stones is not enough for the resistance against the move of rail and sleeper structure. The lamellar structure of the rock also reduces the life of ballast stones, as damage progresses along crevice of rocks. Another is in the size of the ballast stones. As shown in Figure 5.3.2, there is a large quantity of big sized stones mixed among the regular size. They tend to cause damages to trains, and also the derailment of trains.

Source: JICA Study Team

Figure 5.3.2 Distribution of Extremely Big Size Ballast Stones

(4) Rail

The existing rail is 37kg/m rail and a single rail length is 12m long. The track in which 12m length rails are connected is like wire which bends every 12m. Whenever train runs on the joints, it causes a rolling move and a noise which harms the comfortable ride of the passenger. In addition, the train speed is greatly limited. Regarding the weight of rail, the 37kg/m rail is permissible against the stress of the current load of P=12.5 tons in both the outside rail and the inside rail at curved sections. However, in the load of P=20 tons expected in the future, the 37kg/m rail is not permissible against its stress. Regarding the joint section of rails, two typical problems were found. One is that part of the rail head at rail joint was broken and missing, which is shown in Figure 5.3.3. It is necessary to investigate such problems along the route. In motorcar investigations on the both lines between Naypyidaw and Mandalay and between Naypyidaw and Taungoo respectively, there two rail joint spots lacking rail fish bolts were found, which is shown in Figure 5.3.4. The same problems are estimated in considerable number of spots on the whole line.

Source: JICA Study Team

Figure 5.3.3 Damage at rail head

Source: JICA Study Team

Figure 5.3.4 Missing of Rail Fish Bolts

(5) Track Inspection

The method of the current inspection of track by MR depends on inspectors' on-site inspection by observing track conditions. If some problems are found, the inspector issues the repair order with the spot identification to a work group. However, this method depends on only individual decision and it is impossible to secure the standard level of track condition. It is highly recommended that MR introduces a measuring system using instruments which measures track irregularity.

(6) Track Maintenance

Track maintenance works of MR are basically carried out by manpower. It is said that the necessary number of the workers is always in shortage, because the wages for the work is very low even though the labour is very hard under the hot weather condition. If such a condition continues and there is no improvement, the track repair works will not be able to catch up with the necessary level of track maintenance. It is highly recommended that MR promotes track maintenance by using mechanical power.

(7) Turnout

On the rail surface of many turnouts, damages are observed. In addition, gaps are found between fastenings and the main rail/tongue rail/crossing in many turnouts, in which the fastenings are missing. It should be very dangerous to operate trains not only at current speeds but also at high speeds. The improvement of the current condition of turnouts should be the first priority. The sample cases at Pinmana Station are shown in Figure 5.3.5 and Figure 5.3.6 In the rehabilitation project, all the turnouts are planned to change to 50kgN turnouts fit for high speed train operation. On the other side, as the maintenance of turnout requires high level observation skills and mechanical ability, a training program of turnout maintenance for MR staff and workers is highly recommended to be established.

Source: JICA Study Team

Figure 5.3.5 Turnout Damage at Pynmana Station

Source: JICA Study Team

Figure 5.3.6 Turnout Damage at Pynmana Stat

(8) Track Condition in Railroad Crossing

It is observed in many cases of railroad crossings in which earth, sand and garbage clog up the gap between the main rail and railroad crossing guardrail, as shown in Figure 5.3.7. In this case, the flange of the wheel of train hardens the earth, sand and garbage to a rock-like matter, which causes flange-climb derailment. An example of the kind of derailment is observed at the railroad crossing at 212km crossing point. The 50m long derailment trace was found on the top surface of the sleepers near the railroad crossing on the down line, which is shown in Figure 5.3.8 and Figure 5.3.9. It's kind of railroad crossing problem that should be one of the serious issues in operating the trains at high speed. One recommended measure is to insert a rubber bar in the gap between main rail line and guardrail. When the wheel flange runs on the rubber bar, the rubber bar jumps up and at the same time the earth, sand and garbage are blown off. This is a proven method used by railways in Japan.

Source: JICA Study Team

Figure 5.3.7 Railroad Crossing at about 212 kmi from Yangon

Source: JICA Study Team

Figure 5.3.8 Derailment Trace at about 212 kmis from Yangon Starting Point

Source: JICA Study Team

Figure 5.3.9 Derailment Trace at about 212 kmis from Yangon Starting Point

(9) Current Condition of the Sleepers on Bridges

The current condition of the wood sleepers on bridges is defective in many portions. Many wood sleepers have been rotten. Among them, there is considerable number of sleepers, of which major part of the wood is broken and missing or the inside of the wood is hollow. In addition, some sleepers are not fixed in the right angle position to the rails, some sleepers are warped, and different length sleepers are mixed among regular size sleepers. Some dog nails have almost fallen out. Figure 5.3.10 and Figure 5.3.11 show the conditions.

Source: JICA Study Team

Figure 5.3.10 Inside of Sleeper becomes Hollow

Source: JICA Study Team

Figure 5.3.11 Bridge Sleeper Damage

(10) Current Track Condition of Myohaung Freight Station Yard

The lead track area of Myohaung freight station yard is like a dump site full of scattered garbage. The condition of the tracks of the yard is shown in Figure 5.3.12 and Figure 5.3.13. The rail wave up and down, and right and left.

Source: JICA Study Team

Figure 5.3.12 Lead Track Area of Myohaung Freight Station

Source: JICA Study Team

Figure 5.3.13 Track Condition of Myohaung Freight Station

(11) Others

A large quantity of garbage is thrown inside the track area especially in the neighborhood of the stations. Even at such a main large station as Naypyidaw, garbage is often burnt in the drainages between lines, and the area is veiled by the smoke and flame. These conditions should be solved not only from the stand point of the facilities' maintenance but also from the stand point of thesafe operation of trains.

Source: JICA Study Team

Figure 5.3.14 Large Quantity of Garbage Thrown

Source: JICA Study Team

Figure 5.3.15 Burning Garbage in the Drainage Inside of Track Area at Naypyidaw Station

5.3.2 Problems and Countermeasures for Current Track

(1) Current Track Conditions and Problems

Current track conditions and problems are as follows.

- The present 75lb rail used by MR cannot be applied in the case of maximum speed of 100km/h of train. Because the stress degree to the rail caused by 100km/h train speed exceeds permissible stress degree of the rail.
- When 75lb rail is changed to JIS 50N rail, the PC sleeper should be also changed, because the width of the fastening anchorage embedded in the current PC sleeper is narrower than the base width of the 50N rail.
- As many current turnouts have been damaged and many parts of turnout were lost, the 100km/h train operation is impossible at the straight direction side of the turnout.
- The track maintenance condition is poor in the whole line, and the train maximum speed is enforced to be less than 50km/h.

- There are many areas where the quantity of the ballast is much less than the standard defined by MR, and in the areas the end faces of both sides of PC sleepers are exposed, which largely decreases track lateral resistance power.
- Regarding railroad crossings, in many crossings, earth, sand and garbage are clogged up and solidified between guardrail and main line rail, which is in danger of causing derailment when train wheels pass on them.
- The sub ballast seems to disappear on visual observation.
- Train running is in the face of danger of derailment in several sections because of frequent theft occurrence of rail fastenings.

(2) Improving methods for 100km/h train operation

The recommendations to solve the problems mentioned above and to secure 100km/h train operation are as follows.

- The rail of main line and sub-main line should be changed to JIS 50N rail basically.
- PC sleepers fit for JIS 50N rail should also replace current sleepers.
- The turnouts of main line and sub-main line should be changed to # 12 turnouts basically.
- The track maintenance systems should be improved.
- Continuous welded rail (CWR) should be installed for reliable 100km/h train running and improvement of passenger's riding comfort.
- The sub-ballasts should be improved.
- The ballast should be fulfilled in necessary sections. The current status of the quality of ballast should be investigated. If poor quality is found, the ballast should be changed to MR standard.
- About the railroad crossing, the rubber pad should be installed between main rail line and guardrail. It is proved in Japan railways that the earth, sand and garbage between rails pop out when a train drives on the line with rubber pad.
- FD clip should be installed in the sections of frequent occurrence of the theft of rail fastening devices.

5.3.3 Recommendation for Improvement of Track and Subballast/Roadbed

The key factors of the track structure was decided basically same as Yangon-Mandalay Railway improvement project phase-I.

(1) Rail

The calculation result of the comparison between “Bending Stress of the Rail” and “Allowable

Bending Stress of the Rail" is shown in Table 5.3.2. The prerequisites are (1) the comparison between BS75 (37 kg/m) rail and JIS (Japanese Industrial Standards) 50N rail, (2) the maximum axle loads are P=20 tons,16 tons and 14 tons, (3) allowable bending stress of JIS 50N and BS75 (37 kg/m) is 131.2 Mpa and 111.0 Mpa, respectively. (4) Calculations are made on both the outside and the inside of the rail at curved sections. The result shows that the stress of BS75 (37 kg/m) rail is beyond allowable level in all cases of the three types of axle loads except 14 tons (inside). On the other side, the stress of JIS 50N rail is less than the allowable level in the all cases of three types of axle loads even 20 tons (outside). Regarding the marketability of JIS 50N rail and UIC 54, the both have the similar marketability. However, from the price point of view, as the weight per unit of JIS 50N is less than UIC 54, JIS 50N has much advantage. The selection of JIS 50N is highly recommended. However, at Myohaung Freight Station, it is reasonable to use 37 kg/m rail.

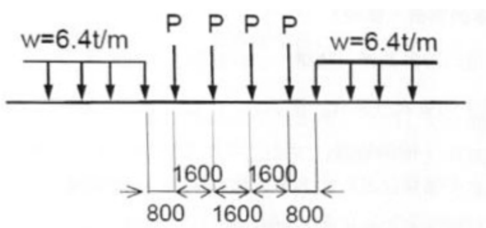
Table 5.3.2 Allowable Stress of the Rail

Rail / Axle load	JIS 50N (Mpa)	BS75 (Mpa)	Remarks
20ton (the outside)	108.4<131.2	160.2>111.0	The permission bend-ing stress degree of the rail is 13.2 Mpa in JIS 50N and 111.0 Mpa in BS75 (37 kg/m).
20ton (the inside)	96.4<131.2	142.5>111.0	
16ton (the outside)	86.7<131.2	128.2>111.0	
16ton (the inside)	77.1<131.2	114.0>111.0	
14ton (the outside)	75.9<131.2	112.1>111.0	
14ton (the inside)	67.5<131.2	99.7<111.0	

Source: JICA Team

(2) Design Load

Regarding the design load, the final report of "Republic of the Union of Myanmar Yangon/Mandalay Detail Design Investigation Phase I" is followed.



Source: JICA Study Team

Figure 5.3.16 Train Design Load

(3) Track Structure

Regarding the track structure, the final report of YMDD phase 1 is followed for Phase 2.

Table 5.3.3 Specifications of the Track Structure

Structure Contents	General Section	Safety Improvement Section
Rail	50N rail (JIS standard) CRW long rail	50N rail (JIS standard) CRW long rail
Sleeper	New PC sleeper (1,760 pieces/km)	New PC sleeper (1,760 pieces/km)
Fastening	Round-bar clip (made in China)	FD clip
Depth of Ballast	250mm under sleeper	250mm under sleeper
Depth of Sub-ballast	300mm	300mm
Turnout	Turnout for 50N rail	Turnout for 50N rail
Max. Speed of train	100km/h	100km/h
Burden of Track	The track structure that can be worthy of 100km/h with 20ton axel lord.	The track structure that can be worthy of 100km/h with 20ton axel lord.

Source: JICA Study Team

(4) Basic Specifications of Design

Regarding basic specifications of the design, the final report of YMDD phase 1 is followed.

Table 5.3.4 Basic Specifications of Design

The train maximum speed in the main line	Diesel-Electric Multiple Unit (DEMU) :100km/h
The train maximum speed in the main line	UIC (P=20ton) lord :100km/h *Union International des Chemines de Fer (UIC)
The train maximum speed in the main line	The maximum speed of existing train is defined according to MR standard as follows. 10mph (16.09km/h) ~ 45mph (72.42km/h)
The train maximum speed in the secondary line	25km/h~40km/h
The train maximum speed in the sidetrack	25km/h
The train maximum speed in loop line and its sidetrack	UIC (P=20tons) lord :10km/h
Maximum axel load	UIC (P =20 tons) (Except Ywathagyi Yard, where P=20 train is not expected.)
Plane curve radius	R≥500m (R≥160m in special case)
Maximum gradient	10 ‰
The maximum temperature of open air	43.1°C
The minimum temperature of open air	7.0°C

Source: JICA Study Team

(5) Specification and Definition

Table 5.3.5 Specification and Definition

Track	Item	Specification and Definition
Track Gauge	Whole line	1,000mm: meter gauge.
Train lord	Whole line	UIC train lord (P=20ton)
Rail	Main line Secondary line and others	JIS 50N Rail : Continuous welded Rail in possible max lengths. BS 75 lbs : Supplied by MR from its rail in storage.
Fastening	Round-bar clip type FD clip type	Supplied by MR, as MR manufactures or buys it. Supplied by MR, after MR buys it.
Ballast	Materials Sectional form	Supplied by MR, as MR buys them. Secure more than 400mm from the end of the sleeper to the shoulder of the ballast, and the incline of the ballast is less than 1:1,8.
PC sleeper	Load of UIC Concrete strength	Axel load 20 tons. Supplied by MR, as MR manufactures them. More than 500kg/cm^2 (50N/mm^2)
Turnout and so on	Main line Side line and others	In No.12 or No.10 high-speed turnout, the train speed at the straight line side is limited to 100 km/h. In the case of No.8, the speed is limited to 90 km/h. No.8 turnout is used and the speed in the yard is 25 km/h. (But in the case of UIC train lord (P=20tons), the speed is limited to 10 km/h.)

Source: JICA Study Team

(6) Speed limit in the curve

Regarding train speed limit on the curves, the final report of "Republic of the Union of Myanmar Yangon/Mandalay Detailed Design Investigation-Phase-I" is followed.

Table 5.3.6 Speed Limit on the Curves

Curve Radius (m)	Speed Limit (km/h)
more than 500	100
450-500	95
400-450	90
350-400	85
300-350	75
300-250	70
200-250	60
150-200	50
100-150	40

Source: JICA Study Team

(7) Speed Limit in Turnout and Scissors Crossing

Regarding the train speed limit in turnout and scissors crossing, the final report of "Republic of the Union of Myanmar Yangon/Mandalay Detailed Design Investigation Phase-I" is followed. On No.12 or No.10 high-speed turnout and scissors crossing, the train speed at the straight line side is limited to100 km/h. In the case of No.8 turnout and scissors crossing , the speed is limited to 90 km/h. In branch line side of turnout and scissors crossing, train speed limit is defined as Table 5.3.7.

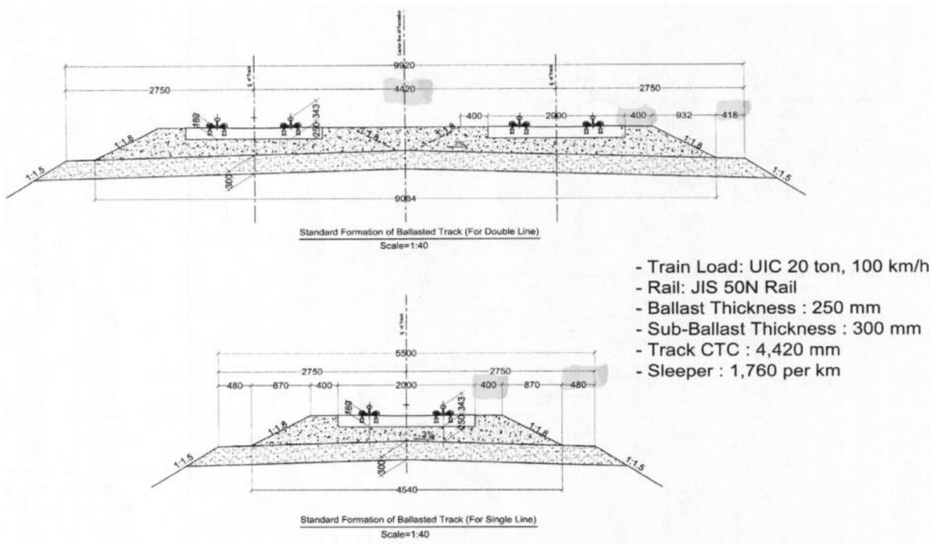
Table 5.3.7 Speed limit in the turnout in Branch Line Side

Number of Turnout	Speed Limit
No. 8	25km/h
No.10	35km/h
No.12	40km/h

Source: Japan Railway Standard

(8) Basic Track Section

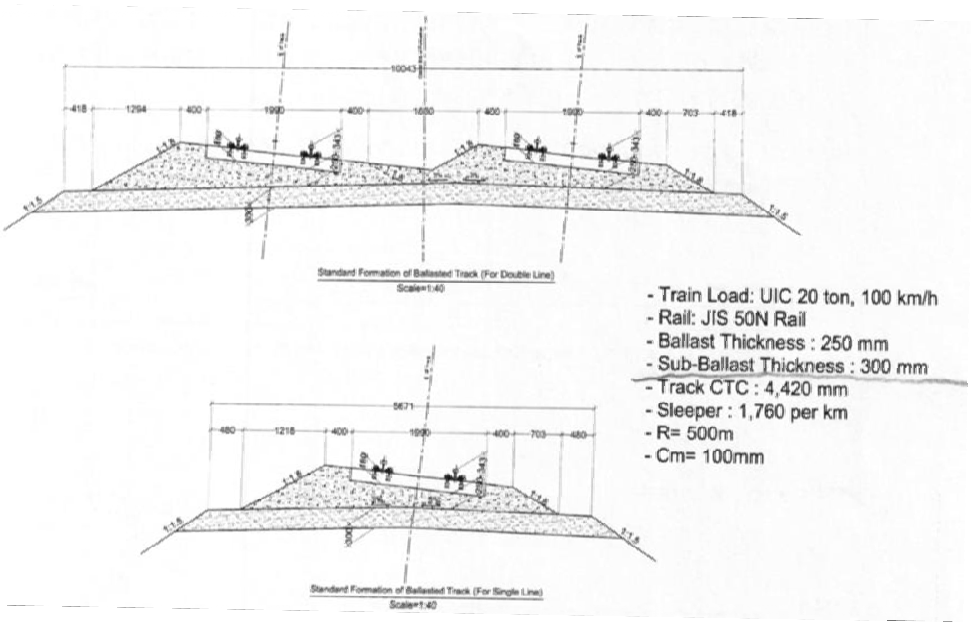
1) Straight Section



Source: JICA Study Team

Figure 5.3.17 Standard Track Section in Straight Line]

2) Curve Section



Source: JICA Study Team

Figure 5.3.18 Standard Track Section in Curve Line

(9) Design of Continuous Welded Rail (CWR)

The design conditions of continuous welded rail (CWR) are as follows.

- Double track main lines using JIS 50N rail are designed as CWR.

  The condition of curve radius is R ≥ 300.

  Turnouts are included if above conditions are satisfied.

- Secondary lines and side tracks are NOT designed as CWR.
- Steel bridges in Length ≤ 20m are designed as CWR, if the both sides of the bridges are CWR.
- Steel bridges in Length > 20m are NOT designed as CWR.
  - (Reason: Wood sleepers of bridges are fixed by dog nails, of which fastening strength is weak.)
- PC bridges and boxes with ballast tracks in double track main line with JIS 50N rail are designed as CWR.

  The condition of curve radius is R ≥ 300.

  Turnouts are included if the above conditions are satisfied.

- PC bridges and boxes in vice-main lines and side tracks are NOT designed as CWR.

- The setting temperature (zero stress temperature) of CWR is between 32.5°C and 37.5°C.The setting temperature (zero stress temperature) is defined in the weather conditions between Yangon and Tongue.

Tmax	: Maximum rail temperature	63.1°C
Tmin	: Minimum rail temperature	7°C
T_0	: Setting temperature (zero stress temperature)	32.5°C~ 37.5°C

- At the setting temperature (zero stress temperature) of 32.5°C~ 37.5°C, thermal stress load to rail becomes ± 30.6°C. On the other side, as the thermal stress load of JIS 50N rail is ± 35.0°C, JIS 50N rail is fully fit for CWR.

(10) Pre-stressed Concrete Sleeper and Fastening

The pre-stressed concrete sleeper (PC sleeper) and fastenings are manufactured and supplied by MR.

- Regarding fastenings, round bar clip is expected to be used in general sections and the FD clip is expected to be used in the secitons where clip thefts have happened very often. In any cases of manufacturing E clip by MR or purchasing from other countries by MR, the design of the E clip should be fit for the newly designed pre-stressed concrete sleeper, to which procedure careful attention should be paid.
- MR has 9 sleeper production plants, in phase 2 section, it is necessary to produce more than 1.3 million sleepers. It is recommended by supervising factory management expert to MR for efficiency production.
- It is necessary to secure enough budgets for production of sleeper.

(11) Ballast

The current deficiency of ballast is serious along the track between Yangon and Mandalay. The 100 km/h train operation planned in this project requires not only continuous welded rail (CWR) but also enough resistance strength of sleepers and ballast against the stress from the buckling of CWR. On the other side of installing JIS 50N rail in the condition of CWR and PC sleeper, it should be absolutely necessary to install enough volume of ballast which satisfies the "Standard Section".

(12) Turnout

The train operation at the speed of 100 km/h requires JIS 50N Rail High Speed Turnout.

Regarding Myohaung Station yard, even though the track, the sleeper, the turnout and others are newly replaced, as the train operation is at low speed, 37kg/m rail, sleeper for 37kg/m rail turnout by 37kg/m and other items for 37kg/m are adopted.

(13) FD clip

The theft section of E clip is shown in the figure 5.3.19. Total length is around 47km. according to the request from MR, it is installed at the section of CP 203 and CP 204 including theft sections.

Ministry of Transport and Communications
Myanma Railways
Yangon-Mandalay Railway Improvement Project,Phase- II
Thief Locations for Clip

Sr; No;	Between Station		Between Mileage		Distance	Special Case on the Location	Remark
	From	To	From	To	(mile)		
1	Shwedar	Shanywa	282.5	292.75	10.25	Around this area,there are so many blacksmith and have the record of losses of clips.	Division-5
2	Nyaungyan	Nwarbtoe	299.25	302	2.75	Between this two stations,we have the record of losses of clips.	Division-4
3	Thapyaytaung	Minsu	336.25	352.5	16.25	Past few years,we have experience of losses of clips.	Division-3
	Total				29.25		

Source: JICA Study Team

Figure 5.3.19 Theft section of Fastening

FASTCLIP（FD クリップ）

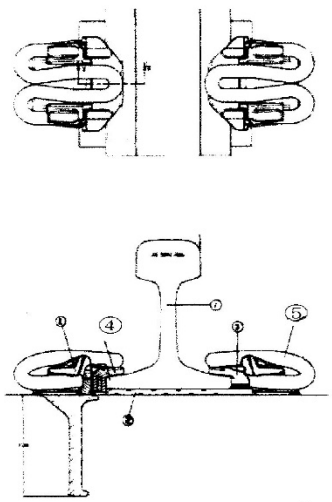


Figure	Name	No
①	SGI shoulder	2
②	Rail Pad	1
③	Insulator	2
④	Toe Insulator	2
⑤	Clip	2

Source: JICA Study Team

Figure 5.3.20 FD Clip Structure

Source: JICA Study Team

Figure 5.3.21 FD Clip Installation work

Source: JICA Study Team

Figure 5.3.22 Rail Road with FD Clip

(14) Points of Attention in Long Rail (CWR) Installation

According to the engineering design, long rail (CWR) is installed in the rail sections of the radius of more than 300m. And turnout is included in long rail (CWR) sections. At expansion joint of long rail (CWR) buffer rail is installed. According to the maintenance record of JR East Japan, in the case of 30,000,000 tons of train passage tonnage per year, the rail of the sections in 300m radius should be changed every several months because of fast wearing out of the rail. As the countermeasure for the rail fast wearing out, JR East Japan makes the rule to install tempered rail in such sections if long rail is installed in the sections. In the case of the railway between Yangon and Mandalay, the change of the rail of 300m radius sections is considered to happen every one or two years, because the train passage is supposed as only 10,000,000 tons. However, it is strongly recommended that tempered rail should be installed in the sections of 300m radius, if long rail (CWR) is designed to install in such sections, because the cost of long rail change is very high.

Regarding the installation of turnout and buffer rail in long rail section should be complicated, and much study and training are highly recommended before the execution.

5.3.4 Current condition and Problems of PC Sleeper Production

(1) Observation Result of PC sleeper Factories

There are 9 PC sleeper factories between Yangon and Mandalay. Among the 9 factories, 5 factories are between Taungoo and Mandalay, all of which are managed directly by MR. There are some differences in the size of areas among them, but the layout of the production lines is almost the same. Regarding the transportation, at 2 factories, finished PC sleepers are carried by rail trolleys to the siding of the adjacent train stations, and at other 5 factories, finished PC sleepers are carried by truck to the nearest train station. From the train stations, the PC sleepers are transported by freight cars to the sites. In the case of being carried by rail trolleys to siding rail, trolley rails are settled at right angle to siding rail. For loading of PC sleepers and transference of molds, large overhead traveling cranes and large gantry cranes are used.

Source: JICA Study Team

Figure 5.3.23 Locations of 9 PC sleeper factories between Yangon and Mandalay

Source: JICA Study Team

Figure 5.3.24 Benches of PC sleeper factory

Source: JICA Study Team

Figure 5.3.25 Molds of PC sleeper (4 PC sleepers can be produced by one mold)

Source: JICA Study Team

Figure 5.3.26 Equipment to pull PC strand steel wire

Source: JICA Study Team

Figure 5.3.27 PC strands

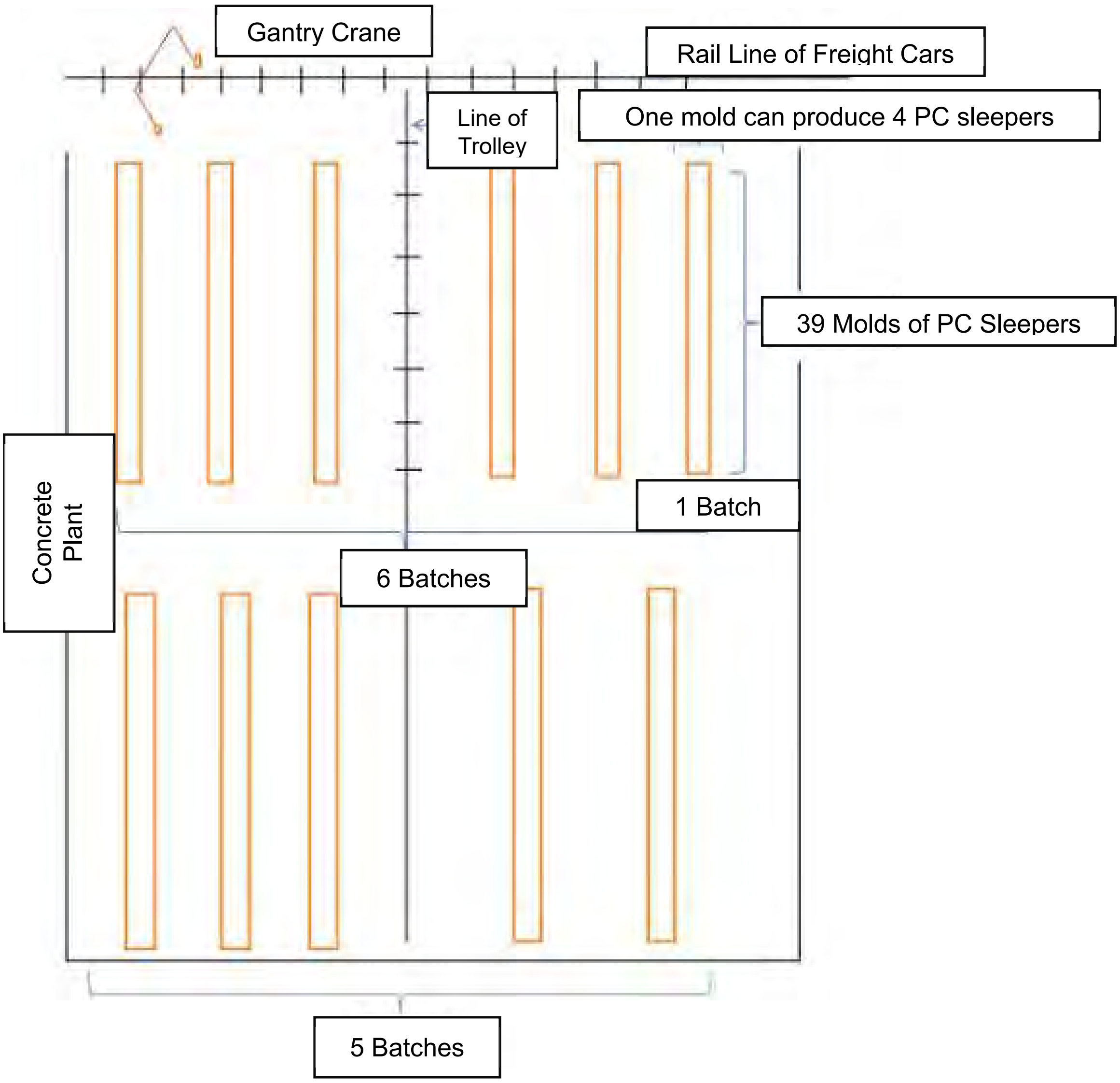
Source: JICA Study Team

Figure 5.3.28 Gantry Crane (Freight cars come under the gantry crane on siding rail)

The layout of production lines is almost the same most at each factory. But the facilities of Michgen factory are old and its production capacity is inferior to other factories because of the narrow factory area. It is said that the improvement plan of the factory is expected in the near future. Regarding the production quality of the factory, this factory still uses single line PC steel wire. But it is improved to use three strands in near future.

(2) Layout of the Production Line of PC sleeper Factory

Layout of production line of PC sleeper factory is as follows.

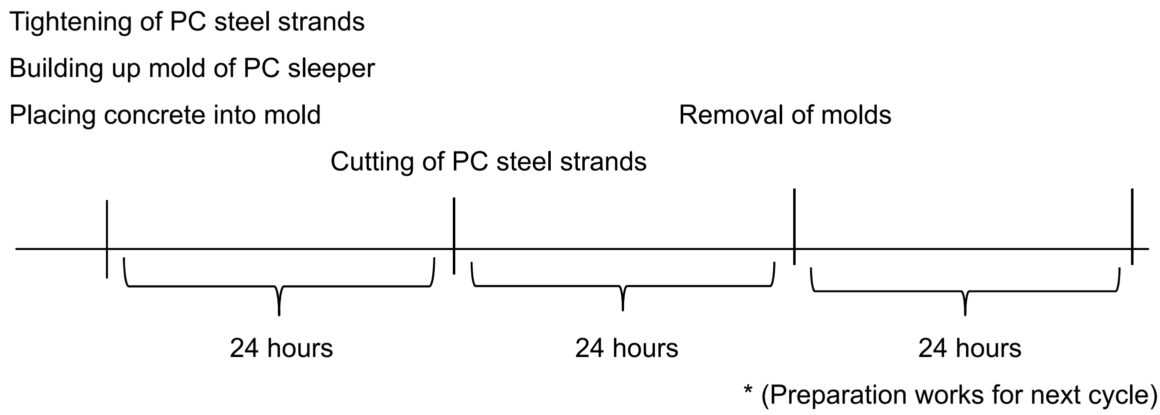


Source: JICA Study Team

Figure 5.3.29 Layout of Production Line of PC Sleeper Factory

(3) Production Cycle

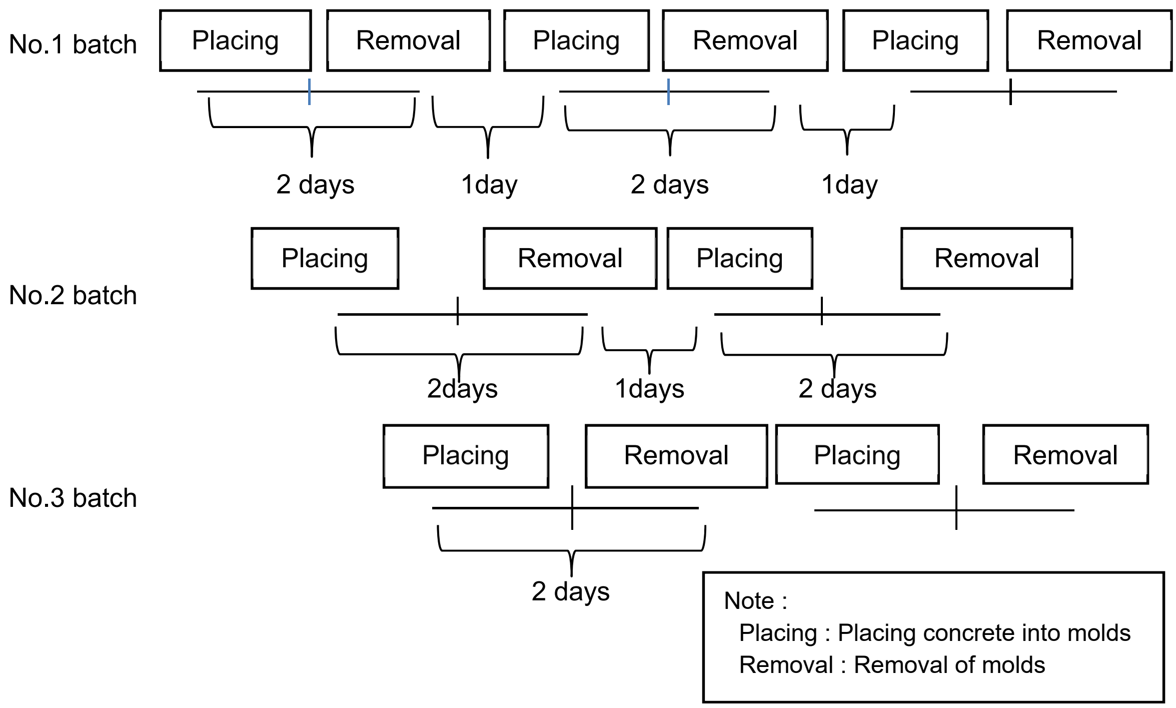
Production cycle of PC sleepers is shown as follows.



* (Preparation works for next cycle) : Cleaning molds, Cutting PC steel strands, Building up the mold of PC sleeper, Assembling the reinforce steel bars

Source: JICA Study Team

Figure 5.3.30 Production Cycle of PC Sleeper (1)



Source: JICA Study Team

Figure 5.3.31 Production Cycle of PC Sleeper (2)

(4) Production Capacity

The project period is 2.5 years including preparation period of 0.5 years. As the result, the net construction period is 2 years. The production capacity of the 5 factories in the 2 years is expected to be produced 1,400,000 PC sleepers. This quantity can meet 1,350,000 which is necessary number for rehabilitation project between Taungoo and Mandalay. Detail is following.

- The number of sleeper produced by one concrete placing:
  39 molds/batch × 4 PC sleepers/mold=1,716 PC sleepers
- The rotation number of 1 batch:
  3days cycle
- The average production capacity per day of 1 factory:
  1,716 × 1/3 = 572 PC sleepers
- The annual rate of operation of factory:
  0.67
- The annual production capacity per 1 factory:
  572*365*0.67 = 140,000 PC sleepers
- The period of the production of PC sleepers:
  2.5 years - (preparation period) 0.5 years = 2 years
- The production number of PC sleeper per 1 factory in 2 years:
  140,000/year × 2 years = 280,000 PC sleepers
- Production capacity of 5 factories in 2 years :
  280.000/factory × 5 factories = 1,400,000 PC sleepers
- Necessary number of PC sleepers for the project:
  1,350,000 PC sleepers
- The production capacity of 5 factories in 2 years of production period satisfies necessary number for the project: 1,400,000> 1,350,000

(5) Transportation Capacity of PC Sleepers

1) Transportation by Freight Trains

The weight of one PC sleeper is approximately 200 kg, and the loading capacity of one freight car is 30tons. As the result, 150 PC sleepers can be loaded on one freight car. If one train consists of 10 freight cars, 1,500 PC sleepers can be transported only one train. As the production capacity of one factory per day is 572 pcs, the capacity of freight train transportation is enough.

2) Transportation by Trucks to the Nearest Station and transferred to Freight Train

The loading capacity of one truck is 12 tons, and the weight of one PC sleeper is 200 kg. Then 60 pcs of PC sleepers can be loaded on one truck. On the other side, in the case of truck transportation, the capacity of loading space of cargo bed. The confirmation calculation is as follows.

- The dimensions of the loading space of truck:
  - Length-7,000mm, Width -2,000mm
- The dimensions of PC sleeper:
  - Length -2,000mm, Width -250mm, Height-200mm.
- Loading method of PC sleeper:
  - Direction of the long side of PC sleeper puts on the direction of long side of the cargo bed.
- Calculation of the number of PC sleeper which can be loaded on the truck cargo bed:
  - On the width of cargo bed: 2,000mm/250mm = 8 PC sleepers.
  - On the length of cargo bed: 7,000mm/2,000mm = 3 PC sleepers.
  - As the height of the PC sleeper is 200mm, 3 layers loading of PC sleeper is reasonable.
  - Number of PC sleepers which one truck cargo bed: 8×3×3＝72 PC sleepers.
  - However, 72 pcs exceeds the loading limit of 60 pcs calculated from the standpoint of the loading weight limit of truck.
  - The conclusion is that one 12 tons truck can load 60 pcs of PC sleepers.
  - For transporting the necessary number of 570 PC sleepers per day, 10 trucks transportation is needed.
- Assuming that the average distance between a factory and a freight station is 30km, the round trip time is estimated as 2hours.
- If one day labor time is 8 hours, 4 round trips may be possible.
- However, in considering the time of loading and unloading, the number of round trips is limited to 3 times.
- From the above estimation, the necessary number of truck is 3~4 trucks. (10/3 = 3.3 ≒ 3~4)
- Although the necessary number of trucks is estimated as 3~4, it is crucial to investigate the following items and establish executable plans.

(1) To investigate the truck operation routes, and to find better choices.

(2) To negotiate freight train arrangement with MR for seeking smooth unloading and loading between truck and train.

(6) Study from Technical Point of View

1) Current Condition

- High-early-strength Portland cement is used.
- Ordinary curing system is applied and steam curing system is not applied
- Myitnge factory applies curing system in the water pool.
- Almost all such facilities as PC strand steel wire cutter, jacks for straining PC strand steel wire, PC sleeper testing equipment are China made, including concrete plants.
- PC steel strand wire is used except Khin-U factory. At Khin-U factory, they have used single PC steel wire, but they plan to change them to strand steel wire.
- The area of Myitnge factory is 14.25 acres (≒58,000m^2), and other factories are rather larger than Myitnge factory.
- Myitnge factory is old and has renewal plan. But there is no renewal plan at other factories, as they have no space to construct new facilities.
- As Khin-U factory was established in 2010 and Pokakku factory was established in 2009, these factories are relatively new.
- The number of employees of the Khin-U factory is 90-100. Other factories are in similar size of employees.
- The life cycle of one PC sleeper mold is 450 times.
- Loading test is carried out on 3 PC sleepers per one batch (156 PC sleepers= 39 molds/batch×4 PC sleepers/mold).
- When one rejected PC sleeper is found in a loading test, the rejected PC sleeper is thrown away and the remains of the same batch are examined by hammer test.
- In KenWoo factory, new PC sleeper molds for JIS 50N rails were already imported from China and are piled up in the factory.
- Hand vibrator is used for compacting concrete in mold at all factories. Mold vibrator is not used.
- The slump of concrete is 30~50mm and the concrete is solid cream concrete. The largest dimension of coarse aggregate is 20mm, and 8mm, 12mm and18mm aggregates are mixed.

- The strength examination by concrete test peace has been executed appropriately in each factory.
- The placing of concrete into mold is performed by hopper hung from overhead traveling crane.

Source: JICA Study Team

Figure 5.3.32 PC sleeper Mold for JIS 50N (China Made)

Source: JICA Study Team

Figure 5.3.33 Loading Test Machine of PC Sleeper

Source: JICA Study Team

Figure 5.3.34 Batcher Plant (China Made)

Source: JICA Study Team

Figure 5.3.35 Hopper for placing Concrete

2) Items of Problem and Recommendation for Countermeasures

(a) Method of PC sleeper Loading Test

The PC sleeper loading test is executed for 3 PC sleepers of 1 batch (156 PC sleepers). The explanation about the test result was that if one rejected PC sleeper is found, the rejected piece is thrown away and all the remains in the same batch are tested by hammer test. But the explanation was not clear to be understood. In the case of Japan railway, PC sleeper loading test is executed at the ratio of one among 50, and when one rejection is found, all the remaining 49 PC sleepers are thrown away. Recommendation is that the reliability of the hummer test is necessary to be confirmed, and if the reliability is confirmed, manual of the hummer test method should be made. The text of the manual is to be distributed to all the factories with providing the instruction course at the factories for requiring performing distinctly the test at the sites.

(b) Protection of Both Sides Surfaces of PC Sleeper

The both side's surfaces of PC sleeper are not protected, and the cutting edges of PC steel strand wires are exposed. For preventing steel strand wires from rust and giving damage other items, it is needed to protect them with cement mortar etc.

Source: JICA Study Team

Figure 5.3.36 Side Surfaces of Finished PC Sleepers

(c) Applying Mold Vibrator

At present, hand vibrator is used to compact the concrete in the mold. It is recommended to try to use and find the superiority of mold vibrator.

(d) Steam Curing

It is recommendable to try to use steam curing.

(e) Checking the Supporting Deck of PC Sleeper Molds

It was explained at a factory that mold supporting decks have never been checked their irregularity of alignment and horizontality since the establishment. It is recommended to check mold supporting decks at all the factories before large quantity of PC sleeper production.

(f) Storage of finished PC Sleeper

It was observed that finished PC sleepers were piled up 13 layers high at the maximum, and some of the piles lean to one side. It is recommended to make manuals how to store finished PC sleepers. The manuals should be distributed to all the factories with the instruction to keep strictly to the manuals. The indication of appropriate supporting points is in particular important.

Source: JICA Study Team

Figure 5.3.37 Stored PC Sleepers

(g) Checking Key Works

Before starting the production of large quantity of PC sleepers, it should be important to review and improve some key works such as the method of fixing rail fastening devices, the method how to assemble reinforce steel bar and the method how to arrange PC steel strand wire etc.

(h) Technical Instruction

It is strongly recognized that the factory staff desires to get technical transfers by experts from anywhere in the world. Therefore, it is necessary to make urgent arrangement for the demand.

(7) Conclusion about Large Quantity Production of PC Sleepers

It was confirmed that the necessary number of PC sleepers for the improvement construction between Taungoo and Mandalay can be supplied in time by the 5 factories under the direct management of MR. At every factory of the 5, the facilities and tools are put in efficiently workable order, and critical point of engineering was not found. Regarding transportation of the large quantity of PC sleepers, critical items is not also found, but such points as construction of more pass-each-other spaces in truck routes, increasing the number of trucks and smooth transference of cargo between truck and freight train should be checked and improved in early stage. The above mentioned items to be improved or to be promoted are recommended to start the arrangements as soon as possible.

5.3.5 Current Status of Ballast Production

(1) Current Status of Ballast Plants

There are 5 ballast plants between Taungoo and Mandalay. One of them is owned by MR and others cooperate with MR. Observation result is as follows.

1) Taung Kant Lant

a) Scale Area : 100acre, Employee: 20, Crusher: 2 sets

b) Production Capacity

145m³/day-set. 145m³/day×30 days ≒ 4,000 m³/month-set.

Production volume per year:

4,000 m³/month-set×12months ×0.67(operation rate)×2 sets≒ 64,000 m³

c) Transportation Capacity

Loading capacity of 1 dump truck (12tons) : 4.4 m³

Turnaround time between plant and station: 45 minutes

Number of round trip between plant and station: 5 trips/day

Transport volume of 1 dump truck per day: 4.4 m³×5 round trips = 22 m³

Transport volume of 1 dump truck per month:

22 m³×30 days ×0.67 (operation rate) = 440 m³

Transport volume of 1 dump truck per year: 440 m³×12 months = 5,300 m³

If 5 pass-each-other road spaces are constructed, 5 dump trucks can be operated between factory and station.

Transportation capacity per year by 5 dump trucks:

5,300 m³×5 dump trucks×0.7 (interchange loss rate) = 20,000 m³

There is no problem in the freight transportation form the station.

For increasing transportation capacity, number of pass-each-other road spaces should be increased.

Source: JICA Study Team

Figure 5.3.38 Crusher

Source: JICA Study Team

Figure 5.3.39 Sifter Steel Plate

Source: JICA Study Team

Figure 5.3.40 Quarry

Source: JICA Study Team

Figure 5.3.41 Road Condition

2) Thent Sin Auna

a) Scale

Adjacent to Bellin Station

Crusher: 6 sets (China and Myanmar made)

Material stone is transported from Sone10km far from the plant.

b) Production Capacity

Production capacity of 1 set of crusher: 135m³/day-set.

Production capacity of 6 sets of crushers: 324m³/day-6 sets.

Production capacity per month: 324m³/day ×30 days =9,720 m³/month

Production capacity per year:

9,720 m³/month×12months ×0.67(operation rate) ≒ 78,000 m³

c) Transportation Capacity

All the volume is transported by freight.

Load capacity of 30t hoper car: 11 m³

Load capacity of 1 train of 30 hoper cars: 11 m³×30 cars= 330 m³

Production capacity per day of 324 m³ is within the capacity of transportation.

Source: JICA Study Team

Figure 5.3.42 Crusher Plant adjacent Station

3) Htone Bo

a) Scale Owned by MR.

Crusher－2sets (Japan and India made)

b) Production Capacity

Production capacity per year of 1 set of crusher: 19,000~20,000 m³/year

Production capacity per year of 2 sets of crushers: 38,000~40,000 m³/year

c) Transportation Capacity

All the volume is transported by freight train.

Source: JICA Study Team

Figure 5.3.43 Crusher

Source: JICA Study Team

Figure 5.3.44 Quarry

4) Taunh Be Lar

a) Scale As vast as 700 acre (300ha) property

Crusher－8 sets

400 Employees

b) Production Capacity

Production capacity per hour of 2 sets of crushers among 8 sets:

50 t/h-set ×2 sets = 100t/h・2sets = 37m³/h・2sets

Production capacity per hour of 6 sets of crushers among 8 sets:

25 t/h-set ×6 sets = 150t/h・6sets = 56m³/h・6 sets

Production capacity per day of all the 8 sets of crushers:

(37+56=93m³)×8 hours =744m³/day-8 sets

Production capacity per year of all the 8 sets of crushers:

744m³/day×365days×0.67(operation rate) = 180,000 m³/year-8sets

(Note) However, as there was found unclear explanation at the survey, detail investigation is necessary.

c) Transportation Capacity

As the width of the 11 miles (17.6 km) road between the plant and Yae Ni Station is wide enough for truck transportation, product transportation capacity can be increased fit for the production volume. However, as the road condition is very rough, the improvement of the road condition on detail investigation should be necessary.

Source: JICA Study Team

Figure 5.3.45 Crusher

Source: JICA Study Team

Figure 5.3.46 Quarry

5) Taungoo

a) Scale As vast as 345 acre (148 ha) property.

Crusher-10 sets (all the 10 sets are china made).

1,000 employees

The plant is expected to be used for Phase-1 construction.

b) Production Capacity

Production capacity per year of 1 set of crusher:

80 t/day-set = 30 m^3/day-set = 900 m^3/month-set ≒ 7,000 m^3/year

(considering 0.67 operation rate)

Production capacity per year of 10 sets of crushers: 70,000 m^3/year-10 sets

c) Transportation Capacity

As the product is transported by truck on the 6.4 km road to Taungoo Station, and transferred to freight train, problems of transportation may not be found. However, the improvement of the road condition on detail investigation should be necessary.

(2) Summary of the Survey on Ballast Supply Status and Study Items

The summary of the survey on ballast supply status of 5 ballast plants between Taungoo and Mandalay is shown in Table 5.3.8.

Table 5.3.8 Current Status of Ballast Production Capacity

Plant Name	Production Capacity per Year	Transportation Capacity per Year	Means of Transportation
Taung Kant Lant	64,000m³	20,000m³	Truck & Rail
Bellin Station	78,000m³	more than 78,000m³	Rail
Htone Bo	40,000m³	more than 40,000m³	Rail
Taunh Be Lar	180,000m³ (Detail investigation is necessary)	180,000m³ (Detail investigation is necessary)	Truck & Rail
Taungoo	70,000m³	70,000m³ (Detail investigation is necessary)	Truck & Rail
Total	432,000m³	388,000m³	

Source: JICA Study Team

As shown above, the total capacity of ballast production per year of the 5 plants is 432,000 m³. The net construction period is 3 years, which is added 0.5 years as preparation period from the gross construction period of 2.5 years. The expected volume of ballast production of the 3 years is expected to be 1,296,000 m³.

On the other side, as the necessary ballast volume for the Phase-2 construction is 1,200,000 m³, it is enough ballast supply volume. To be taken the consideration, as the last one year of Phase-1 construction period is overlapped with the first one year construction of Phase-2, it is necessary enough volume of ballast in advance.

In case it becomes shortage of ballast, it is important to confirm if the quality of the ballast is fit for MR standard and if their cooperation is reliable of third partiy plant. And, if the cooperation is established, the ballast from 5 MR plants is mixed with the ballast from the plants of the third parties, it is necessary to establish the ways of control both of the quality and the supply execution.

About the capacity of transportation, the transportation volume is slightly shortage at the current status, it is necessary to consider increasing transportation capacity. About the truck transportation of Taunng Kant Lant Plant, to increase truck pass-each-other road spaces is especially important, and the construction should be executed on detailed survey.

The quality of the ballast of each plant is acceptable enough. The hardness is enough, and smooth or flat surface stones were not found in the investigation. The sample test result of Taunng Kant Lant Plant is shown in Figure 5.3.47.

TABLE (1) RESULTS OF TEST ON CRUSHED ROCK

Location

Client

Reference (1) :

Reference (2) :

NO	LOCATION	SPECIFIC GRAVITY	ABSORPTION (%)	CLAY LUMP (%)	CRUSHING VALUE (%)	IMPACT VALUE (%)	LOS-ANGELES ABRASION VALUE (%)	TEN PERCENT FINE VALUE (Tons)	REMARKS
1	[illegible]	2.67	0.41	0.12	23.5	21.4	24.3	25	Suitable for Surface, Base and Sub-base Courses.
	[illegible] Specification For Surface Course	2.5 - 3.0	2.0 (Max)	2.0 (Max)	20.0 (Max)	-	40.0 (Max)	11 (Min)	-
	[illegible] Specification For Base Course	2.5 - 3.0	4.0 (Max)	4.0 (Max)	30.0 (Max)	-	50.0 (Max)	11 (Min)	-
	[illegible] Specification For Sub-base Course	2.5 - 3.0	4.0 (Max)	4.0 (Max)	40.0 (Max)	-	50.0 (Max)	5 (Min)	-

Source: JICA Study Team

Figure 5.3.47 Ballast Sample Test Certificate of Taunng Kant Lant Plant

5.3.6 Summary of Quantity and Cost of Track Works

The summary of material & machinery and cost of track works is shown in Table 5.3.9.

Table 5.3.9 Summary of Quantity and Cost of Track Works

Item		Unit	Quantity					Cost		
			Total	Workinng Section				Total (million Yen)	Breakdown of Total Cost	
				CP 201	CP 202	CP 203	CP 204		Yen (million Yen)	Kyat (million Kyat)
				(Km Post) km	(Km Post) km	(Km Post) km	(Km Post) km			
			Total Distance between Taungoo and Mandalay	Taungoo 267.2	Naypyidaw 370.0	Ingyinkan 448.0	Kumelan 549.5			
				Naypyidaw 370.0	Ingyinkan 448.0	Kumelan 549.5	Mandalay 620.5			
			353.3 km	Distance 102.8	Diatance 78.0	Distance 101.5	Distamce 71.0			
1. Rail 50N		ton	73,663	21,418	16,194	20,960	15,091	8,620	8,620	-
2. Rail 37kg		ton	3,663	635	244	830	1,954	-	-	-
3. Track Laying		km	707	206	171	205	125	1,256	-	15,361
4. Turnout	#8.5 50N	set	181	51	31	42	57	1,236	1,158	941
	#12 50N	set	272	74	72	55	71	2,019	1,904	1,414
	Scissors	set	8	3	0	4	1	256	240	187
5. Turnout Tamping (1 set=3 times tampings)		set	490	139	103	115	133	217	-	2,647
6. Buffer Rail		set	136	38	41	28	29	54	54	-
7. Compromise Rail		unit	40	6	9	6	19	14	14	-
8. PC Sleeper (50N)		million pcs	1.35	0.38	0.31	0.39	0.27	717	-	8,780
9. Synthetic Sleeper (for turnout)		pc	12,896	3,120	2,626	3,562	3,588	516	516	-
10. FD Clip (including insulation clip)		million pcs	0.176	-	-	0.176		458	458	-
11. Mould for FD Clip Sleeper		pc	156	-	-	156		187	187	-
12. Concrete Roadbed of Naypyidaw St. and Mandalay St.		m3	18,600	-	9,300	-	9,300	4	-	37
13. Track Works Depot		location	4	1	1	1	1	16	-	200
14. Machinery									-	-
(1) MTT		unit	4					1,440	1,440	-
(2) Flash Butt Welding Machine		unit	4					440	440	-
(3) Portable gas Pressure Welding Machine		unit	4					200	200	-
(4) Track Measuring Machine		unit	3					120	120	-
(5) Portable Ganrty Crane for 200m Rail Renewal Site		unit	40					12	12	-
(6) Gantry Crane (2t)		unit	47					47	47	-
(7) Wagon for carring 200m Long Rail		unit	1					60	60	-
Reference: (Total Cost of Machinery)								2,319	2,319	-

TOTAL		17,889	15,470	29,567

[Note-1]
The item of "(3)Track Laying" includes such 6 items as follows in figures in lumps :
(1) Ballast, (2) Renewal of Rail, (3) Track Tamping by MTT (3 times), (4) Rail Flash Butt Welding, (5) Rail Gas Welding, (6) Fish Plate

[Note-2]
However, as " Ballast " and " Sub Ballast " are the major materials of track & civil works, the estimation of necessary volume of the 2 materials is shown in the following table. The figures of [Sub Ballast] are to be added up in Civil Works Quantity & Cost.

Item	Unit	Quantity				
		Total	Workinng Section			
			CP 201	CP 202	CP 203	CP 204
			(Km Post) km	(Km Post) km	(Km Post) km	(Km Post) km
		Total Distance between Taungoo and Mandalay	Taungoo 267.2	Naypyidaw 370.0	Ingyinkan 448.0	Kumelan 549.5
			Naypyidaw 370.0	Ingyinkan 448.0	Kumelan 549.5	Mandalay 620.5
		353.3 km	Distance 102.8	Diatance 78.0	Distance 101.5	Distamce 71.0
Ballast	million m3	1.20	0.35	0.27	0.34	0.24
Sub Ballast	million m3	1.64	0.49	0.38	0.44	0.33

Source: JICA Study Team

5.4 Earth Work

It is important that the required standard cross section, soundness of embankment, stability of ground, etc. against expected train load are secured for the earth structure. In this study, the road bed (sub-ballast) of the earth structure has been completely changed from the FS study (2013: maximum axle load of 17 ton) mainly due to the new maximum axle load of 20 ton (UIC Loading: thickness became 30 cm) that is the target of International Train Operation of AEC (ASEAN Economic Community), and has been the request from the Myanmar Government and MR (Myanma Railways), including securing of the soundness of the embankment, stability of the ground, etc. of the railway facilities in YM-D/D(1). The reason is because the long route length is about 350 km, which is similar in length to YM-D/D(1), it is necessary to design an economical and safe earth structure, e.g., the economical top profile elevations of the embankment; elimination of the ditch at the top slope according to adequate technical aspects; slope protection using sodding, stone pitching, etc. that is popular in Myanmar because of the reasonable cost; and deterrence piles of used rail supplied by MR.

In Section 5.4, sections 5.4.1 Current Conditions of Earth Work, and 5.4.2 Recommendation for Earth Work all will be described in detail.

5.4.1 Current Conditions of Earth Work

(1) Existing Embankment Conditions

1) Embankment Age

Embankment age affects strength and stability. Normally for the embankment, the older, the better, while for cut slopes, the older, the worse in strength and stability.

The existing railway embankment works between Yangon and Mandalay have been carried out in three periods. The first was during a period when Lower Burma was a British colony in the 19th century. The second was between 1971 and 1973. The latest one was carried out between 1996 and 2007 under a tight schedule.

The first and second embankments are more than 40 years old, which are supposed to be old enough in strength and stability. These will be called ‘OLD’ embankments. The latest are recently constructed. These will be called ‘NEW’ embankments, which may have some problems in strength or stability. Also, consolidation settlement may be another problem in ‘NEW’ embankment sections. The following Figure 5.4.1 shows existing conditions of Embankment at some locations.

2) Embankment Conditions

(a) Settlement due to soft ground (Mile 82)

(b) Settlement due to soft ground (Mile 146)

(c) Settlement due to erosion by stream (Mile 243)

(d) Settlement due to unstable embankment (Mile 336)

Source: JICA Study Team

Figure 5.4.1 Existing Conditions of Embankment

The flooding area is spreading in most of the Yangon-Mandalay Railway line. Some have happened due to discharge from the nearest dam, and some are due to heavy rain and stream flooding.

In addition, MR has given information about sections where there is adverse settlement, where ballast maintenance work was frequently required for safe railway operation. The adverse settlement is taking place at the section of OLD embankment, which was constructed in marshy places. It also happens at sections of 'NEW' embankment.

According to the above information, two types of causes of the settlement are considered. One is due to soft ground under the embankment. Sliding in the soft ground seems to be occurring at OLD embankment sections. The other is due to problems in NEW embankment, such as the lack of strength and stability, or erosion. Based on the site inspection, it seems that erosion and water paths occurring in the embankment is a main cause of the settlement. In addition, it seemed that there was an insufficient amount of fill compared to the standard dimensions of embankments which was found in many places.

At Mile 357, stone pitching was found to be constructed in the latest embankment period. MR stated that the stone pitching was a countermeasure that was constructed to prevent erosion and adverse settlement. At present, there is no adverse settlement even in the rainy season.

The following Figure 5.4.2 and Figure 5.4.3 show lack of fill in the embankment and stone pitching to prevent erosion respectively.

See Appendix 5.4.1.

Source: JICA Study Team

Figure 5.4.2 Lack of fill in the embankment (Mile 44)

Source: JICA Study Team

Figure 5.4.3 Stone pitching to prevent erosion (Mile 357)

3) Geotechnical Surveys

Two types of geotechnical investigations had been carried out during the Feasibility Study (FS) stage between Yangon and Mandalay. There were one bored hole and fourteen hand auger (HA) holes between Taungoo and Mandalay. The bored hole was mainly to take N values in the original ground in order to identify geotechnical characteristics, especially potential landslides and consolidation settlement due to soft ground. The hand auger holes were to take cone resistance values in order to get bearing capacity of the existing embankment.

See Appendix 5.4.1.

4) Landslide and Consolidation Settlement

Based on geotechnical surveys during the YM-F/S stage, soft soil is normally defined as cohesive soil (clay or silt) that has less than 5 in N value. The bored hole at Mile 104 has a 6-meter thick silt layer SPT 3 to 4 between GL（Ground Level)-8.5m and -14.5m. This layer has many seam layers of sand, and consolidation settlement may occur in a very short time during embankment work. It may be assumed that adverse settlement may not happen for a long time. And in the case of up to 3-meter embankment height, landslides may not occur. The other six bored holes don’t have the same kind of soft layer. Therefore, there is low risk of landslide and adverse settlement in less than 3-meter-high embankments in the bored hole locations where the JICA Study Team of YM-F/S has investigated between Yangon and Mandalay.

There were some places where the cohesive soil N values were found to be from 0 to 3 in the geological survey of the YM-D/D (1) study at the sites. The embankments are stabilized as it has been more than 40 years since construction. Because there were no deformed embankments found in the topographical and alignment surveys, the risk, e.g., landslide or lateral flow of the embankment is small if no additional embankment is constructed. Therefore, it is not necessary to carry out any counter measures.

JST suggests that effective geo surveys should be carried out during D/D stage at the following locations even referring to the above information in other studies.

- the up&down line (Mile 184/15- 185/05)
- the down line (Mile 199/14-18)
- the up line (Mile 216/23-24),
- the down line (Mile 220/16-17, 218/21-22, 218/14-16)

5) Bearing Capacity of Embankments

Based on the results of the hand auger investigation at YM-F/S stage, the bearing capacity for the investigated location has been calculated for the embankments. Railway loading is distributed to the embankment through the ballast layer. The distributed loading is critical at the top portion of the embankments. The stress on the existing roadbed has been checked with the allowable bearing capacity from the hand auger investigations.

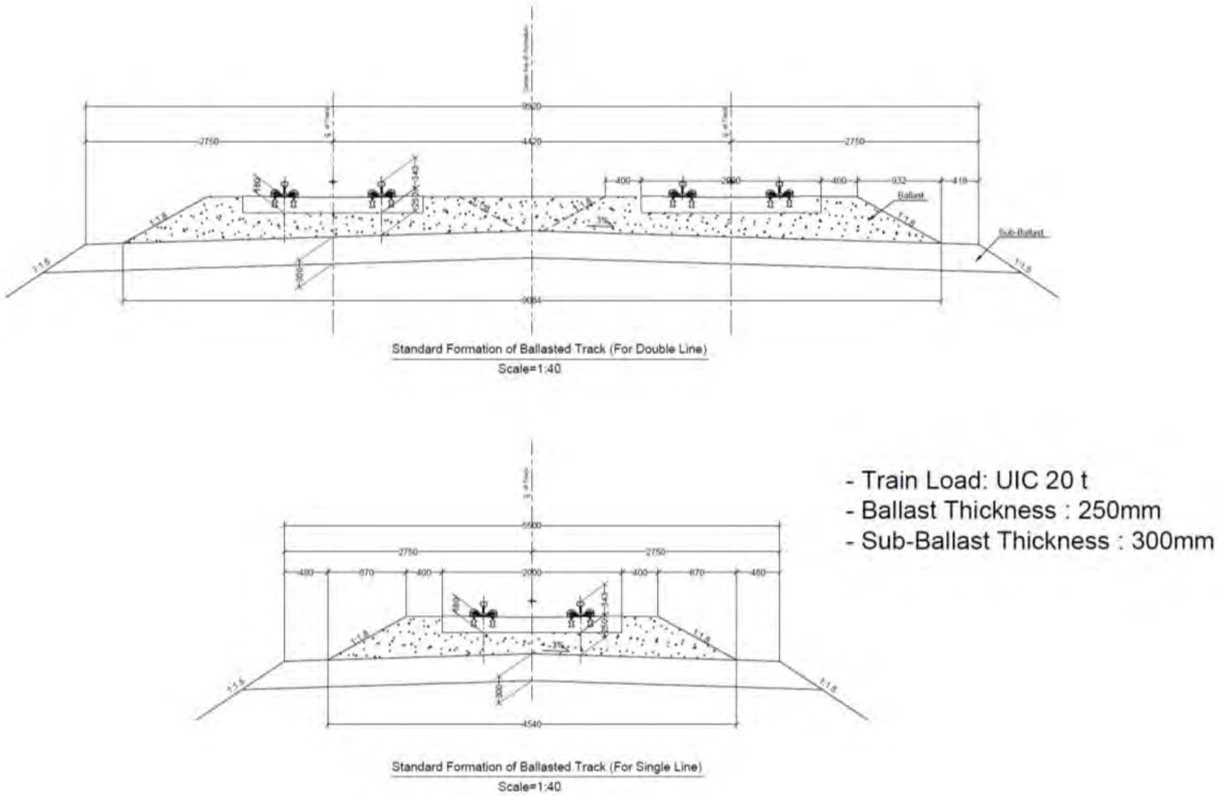
All allowable bearing capacities were more than the calculated distribution loading. Therefore, all embankment structures were adequate in bearing capacity near the locations where HA investigations had been carried out at YM-F/S stage.

However, some upper layers of the embankments were found that have insufficient strength. Therefore, the YM-D/D (1) study team proposed that the investigation/inspection of the bearing capacity of the ground and each additional layer at the site should be carried out. It is also necessary to incorporate this testing requirement in the tender documents in YM phase II project.

(2) Problems for Safe & High Speed Operation

1) Lack of Fill

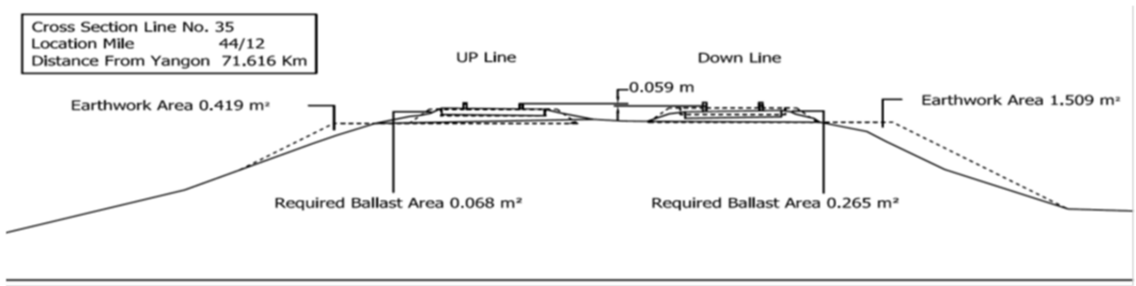
The first problem is the lack of fill compared to the standard formation, which was agreed between MR and the Study Team. These types of embankments were found in many locations during site inspection. The following Figure 5.4.4 shows standard formation for Single and Double lines.



Source: JICA Study Team

Figure 5.4.4 Standard Formation

The YM-F/S Study Team had carried out a topographic survey between Yangon and Mandalay. The total deficiency of volume of the embankments was approximately 368,000 m^3, as indicated in the report of the National Transport Development Plan Rehabilitation and Modernization of Yangon – Mandalay Railway Project Visual Topographic Survey June 2013. Figure 5.4.5 shows the approximate requirement for additional embankment work and ballast filling at Mile 44.

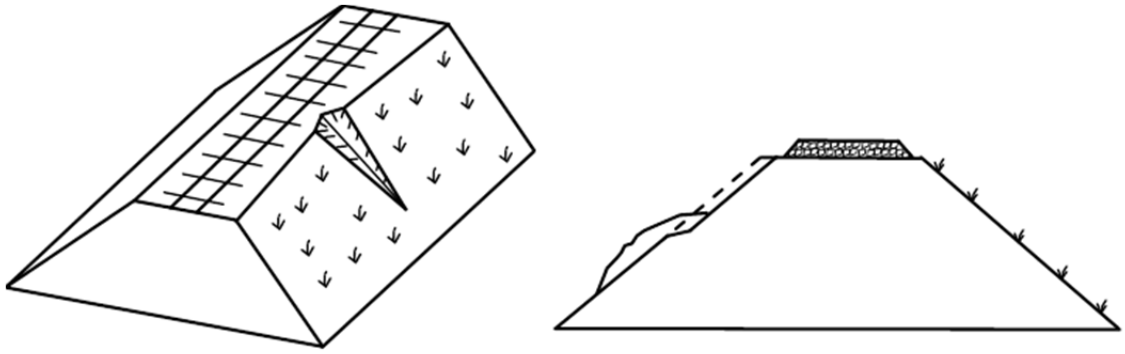


Source: JICA Study Team

Figure 5.4.5 Example of Additional Embankment Work and Ballast Filling - at Mile 44

2) Flooding Area

Even if an embankment is good and stable, in the case of flooding and high water levels in the stream along the embankment, erosion may occur on the slope. This is one of the problems which were observed during the site inspection. Figure 5.4.6 shows settlement due to erosion.



Source: JICA Study Team

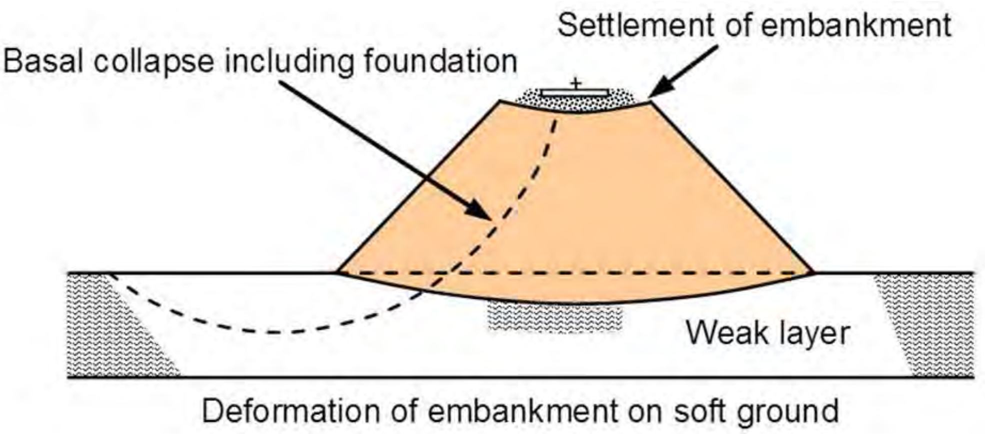
Figure 5.4.6 Settlement Due to Erosion

3) Adverse Settlement

Considerable settlement was found in both OLD embankments and NEW embankments. It is considered that these are happening due to different causes. One is due to soft ground, the other is due to embankment material problems.

4) Soft Ground

An OLD embankment is more than 40 years old, so it is assumed that consolidation settlement should be minimal at the final stage and embankment strength should be adequate to carry the train loads. However, the settlement is continuously occurring, therefore land sliding in soft ground is considered as a cause of settlement in OLD embankments as shown in Figure 5.4.7.



Source: JICA Study Team

Figure 5.4.7 Settlement Due to Land Sliding in Soft Ground

5) Embankment Material Problem

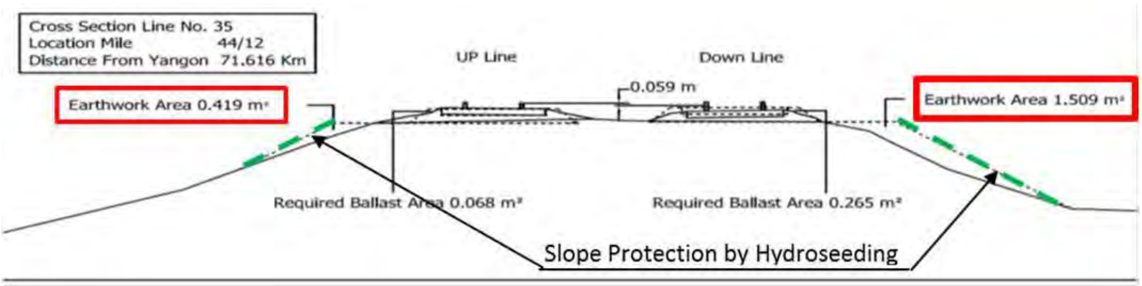
NEW embankment was constructed under the tight schedule and it is assumed that material selection for embankment might not be properly done, so embankment may be easy to have erosion on slope by heavy rain. This problem can be obviously understood from Figure 5.4.1(d) and Figure 5.4.6. ent.

5.4.2 Recommendation for Earth Work

(1) Earthworks to the Standard Formation

For safe and high-speed railway operation, firstly, embankment dimensions should be kept at least to the standard formation which has been agreed between MR and the JICA Study Team as indicated in Chapter 4. These earthworks, including trimming slope and backfilling, should be carried out prior to other rehabilitation measures, such as stone pitching and preventive pile installation. Also, selected suitable material should be utilized for the backfilling. After completion of backfilling work, slope protection should be provided.

Figure 5.4.8 shows Additional Embankment Work at Mile 44.



Source: JICA Study Team

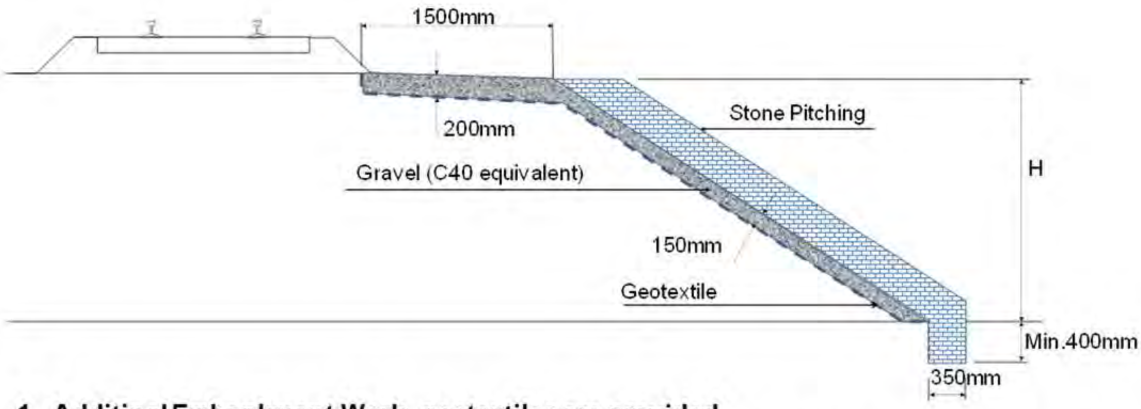
Figure 5.4.8 Additional Embankment Work at Mile 44

(2) Stone Pitching for Flooding Protection

Stone pitching is common in Myanmar and has already been carried out at Mile 357 (upline). It was heard from MR that adverse settlement has never been recorded in this area since the construction of the stone pitching.

A gravel layer and PVC (polyvinyl chloride) pipe also need to be provided for drainage. Geotextile should cover the side of the embankment for separation between gravel and soil.

Figure 5.4.9 shows the details of the method and construction sequence.



1. Additinal Embankment Work, geotextiles are provided.
2. From the toe of the slope, gravel layer and stone pitching are constructed with 2-inch dia. drainage pipes (1 pipe /2m²).
3. Spread gravel and compact it at the top of the embankment.

Source: JICA Study Team

Figure 5.4.9 Stone Pitching

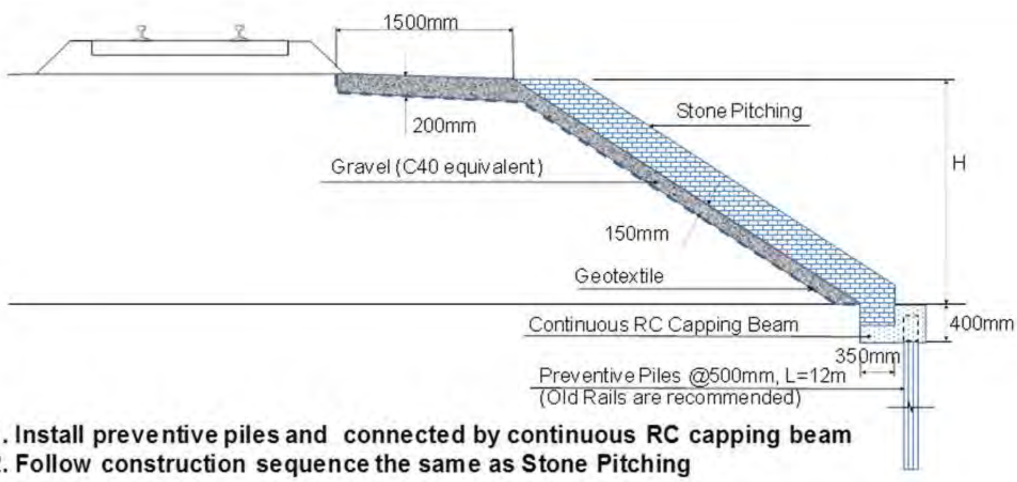
(3) Stone Pitching & Preventive Piles for Preventing Adverse Settlement in Soft Ground

For preventing adverse settlement in soft ground, it is recommended to construct stone pitching and preventive piles, which can be done at a reasonable cost. MR has a lot of old rails, so they can be utilized for preventive piles. The continuous capping beam is essential to integrate the piles and enhance stiffness of preventive structures.

At D/D stage, those locations should be identified based on the geotechnical surveys.

Future settlement cannot be zero, therefore ballast maintenance is still required

Figure 5.4.10 shows the details of the method and construction sequence.



1. Install preventive piles and connected by continuous RC capping beam
2. Follow construction sequence the same as Stone Pitching

Source: JICA Study Team

Figure 5.4.10 Stone Pitching & Preventive Piles

(4) Raising Embankment

At the YM-F/S stage, the raising embankment was not recommended between Taungoo and Mandalay due to flooding, but due to bridge raise up and replacement

The JST will study new flooding data from MR and bridge information, and recommend some portion of the raising embankment in YM phase II project if necessary.

(5) Slope Protection for Normal Embankments

In Myanmar, natural planting on embankment slopes seems to be relied upon. However, if a heavy rain fell just after embankment construction, erosion would occur and the specified dimensions of the embankment could not be maintained. Therefore, slope protection is important to prevent erosion on slopes for safe and high-speed railway train operation.

There are two methods, a turfing method and a hydro-seeding method, to be considered. The turfing method has been applied for this project based on availability in Myanmar and the economic point of view.

(6) Summary of Outline Design for Earth Works

MR has accepted the summary of outline design for earth worksshown in Appendix 5.4.2. This outline design concept is the same as that of YM Phase1.