Islamic Republic of Pakistan

The Ministry of Communications, National Highway Authority（NHA）

Data Collection Survey on Road Landslide Measures in Pakistan

Final Report

January 2019

Japan International Cooperation Agency

Kokusai Kogyo Co., Ltd.

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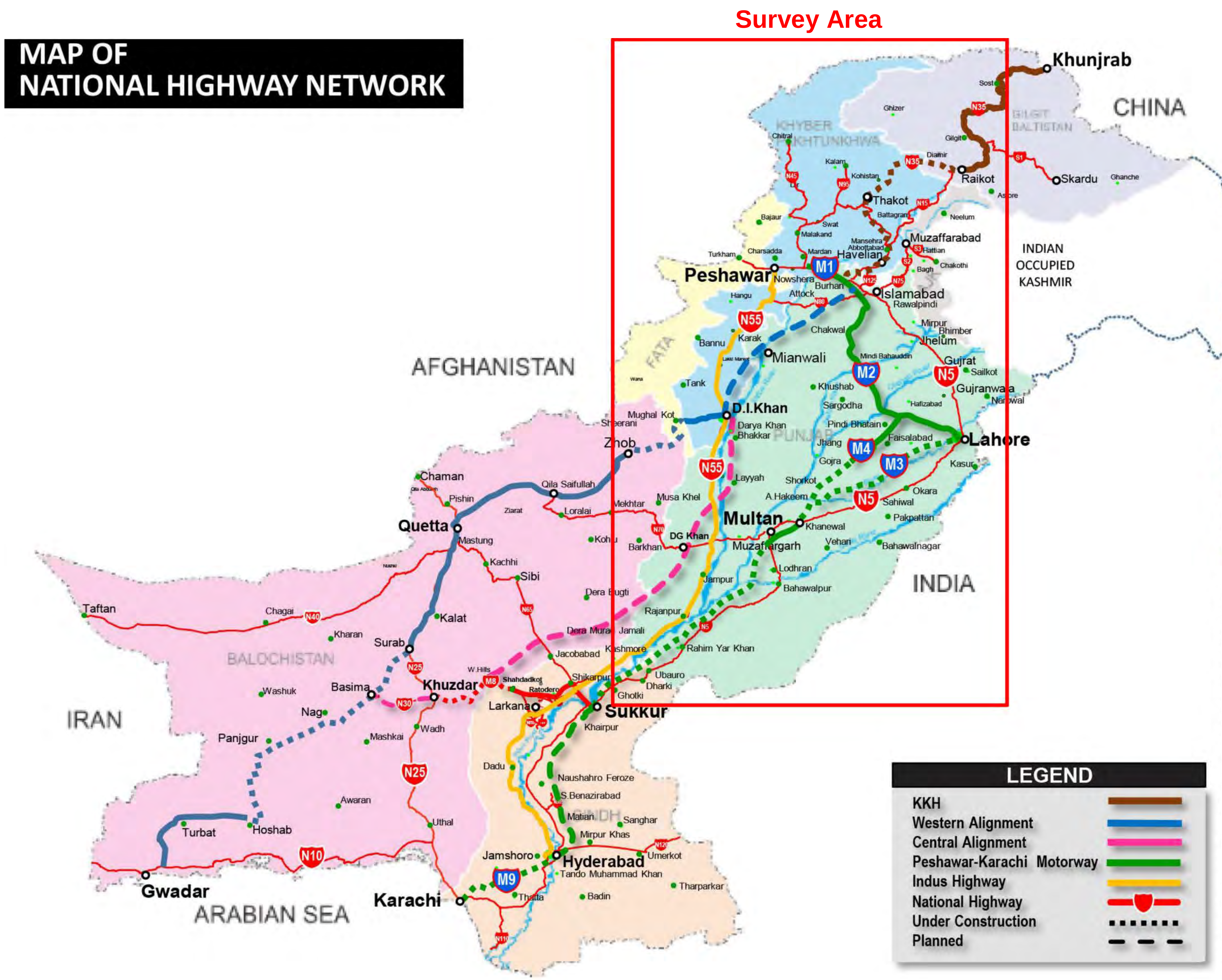

S#	Road Description		Length (kms)
1	Northern Route		784
-	Khunjrab-Raikot		335
-	Raikot-Thakot		270
-	Thakot-Havelian		120
-	Havelian-Burhan		59
2	Western Alignment		2,461
-	Northern Route		784
-	Burhan-D.I.Khan		285
-	D.I.Khan-Zhob		205
-	Zhob-Quetta		331
-	Quetta-Surab		214
-	Surab-Hoshab		449
-	Hoshab-Gwadar		193
3	Central Ailgnment		2,545
-	Northern Route		784
-	Burhan-D.I.Khan (Partial Western Alignment)		288
-	D.I.Khan-Jampur		250
-	Jampur-Wangu Hills		363
-	Wangu Hills-Khuzdar		108
-	Khuzdar-Basima		110
-	Basima-Gwadar (Partial Western Alignment)		642
4	Peshawar-Karachi Motorway		1,512
-	Peshawar-Islamabad		155
-	Islamabad-Pindi Bhattian		235
-	Pindi Bhattian-Multan		298
-	Multan-Sukkur		392
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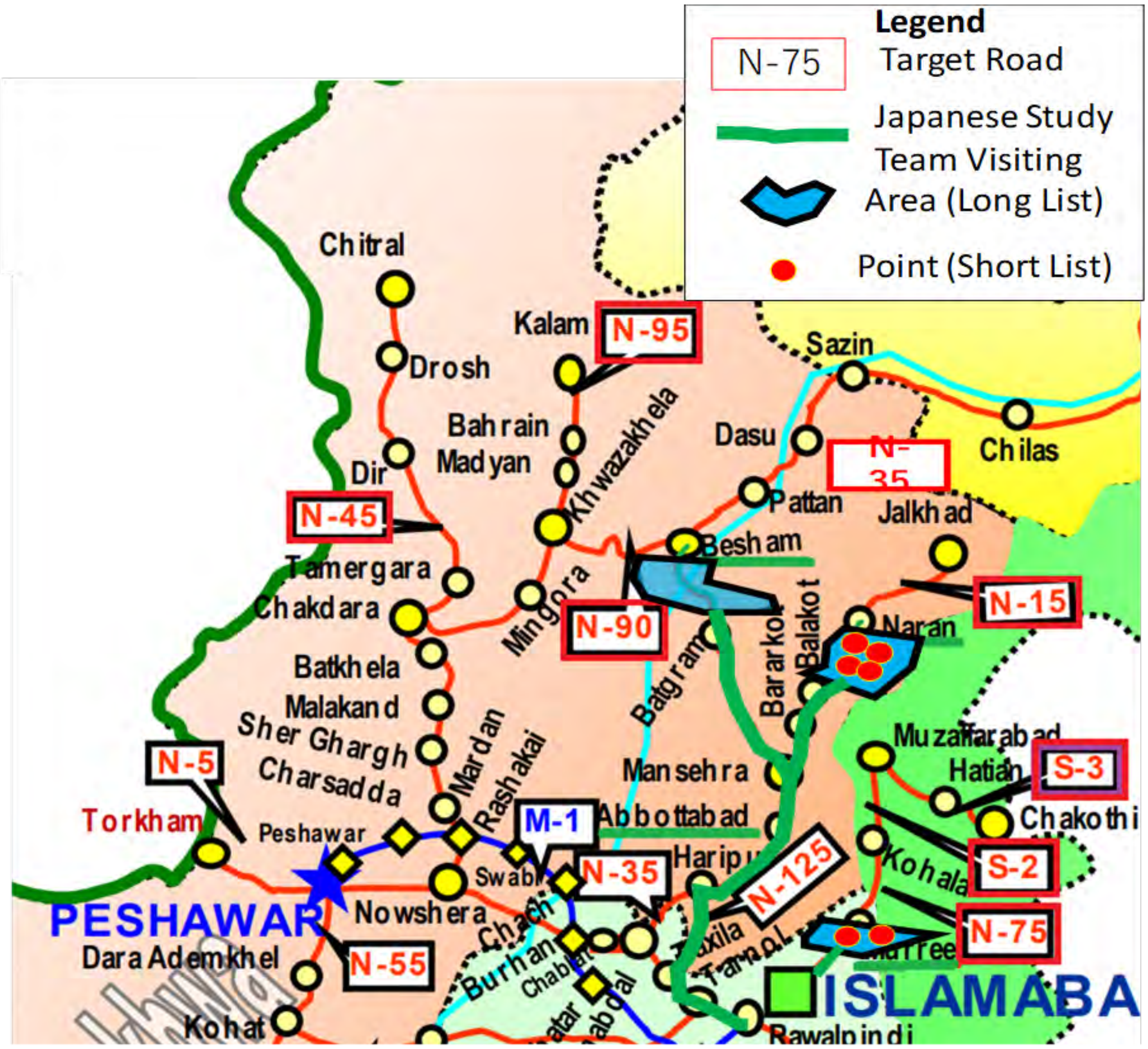
Survey Area Map



Slope Prevention Short List Location Map

Exchange Rate

1 USD	= 113.385000 JPY
1 PKR	= 0.848780 JPY

PKR: Pakistan Rupee

Source：JICA exchange rate, December, 2018

Photographs (1/2)

Photograph 1: Project Discussion with the NHA

Photograph 2: Project Discussion with the C&W

Photograph 3: Seminar (20th April 2018)

Photograph 4: Presentation during seminar (Right: NHA Chairman)

Photograph 5: Site visit with NHA

Photograph 6: Slope failure (N-15)

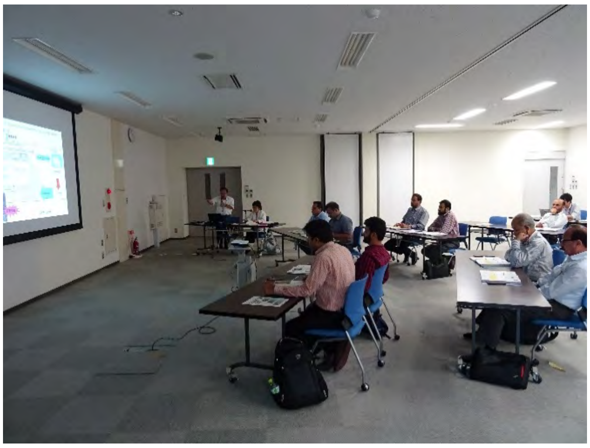
Photographs (2/2)

Photograph 7: Site visit with Japanese companies (N-75)

Photograph 8: Site survey of slope failure along N-15

Photograph 9: Survey Area (N-15)

Photograph 10: Debris flow (N-15)



Photograph 11: Training in Japan

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Abbreviations

Abbreviation	Name
ADB	Asian Development Bank
BOT	Built Operate Transfer
C&W	Communication & Works Department
CAREC	Central Asia Regional Economic Cooperation
CDWP	Central Development Working Party
CPEC	China Pakistan Economic Corridor
DDMA	District Disaster Management Authority
DDWP	Department Development Working Party
ECO	Economic Cooperation Organization
ECNEC	Executive Committee of National Economic Council
EPS	Expanded Poly Styrene
ERRA	Earthquake Reconstruction and Rehabilitation Authority
FWO	Front Work Organization
GM	General Manager
GSP	Geological Survey of Pakistan
HIES	Household Integrated Economic Survey data
IMDC	Islamabad Murree Dual Carriageway
IRI	International Roughness Index
JICA	Japan International Cooperation Agency
JST	JICA Survey Team
KKH	Karakoram Highway
KP	Khyber Pakhtunkhwa
NDMA	National Disaster Management Authority
NDMA	National Disaster Management Act
NDMO	National Disaster Management Ordinance
NHA	National Highway Authority
PC-1	Planning Commission Performa I
PJ	Punjab
PKHA	Pakhtunkhwa Highway Authority
PPP	Public Private Partnership
PSDP	Public Sector Development Program
RAMD	Road Asset Management Division
RMA	Road Maintenance Account
Rs.	Pakistan Rupee
SAARC	South Asian Association for Regional Cooperation
SDO	Sub Division Officer
WB	World Bank

1 Outline of the Project

1.1 Background

Pakistan is prone to experiencing natural disasters. The government of Pakistan has been strengthening its capacity for disaster prevention and reduction since being stricken in 2005 by the Great North Earthquake (M7.6). The roads of Pakistan are the predominant means of economic activity and have been better maintained than those of other South Asian countries. The Ministry of Communications, National Highway Authority (hereinafter, NHA) is responsible for the development and maintenance of national roads, and the Communication and Works (hereinafter, C&W) of each provincial government is responsible for the provincial roads.

However, in the northern province of Pakistan, which has steep and harsh geographical terrain, repeated heavy rains and earthquakes have damaged the road infrastructure. During the rainy season, the mountainous area in the northern region is prone to road disasters, which has led to villages remaining isolated and undeveloped.

In the context of the abovementioned background and given that there is insufficient knowledge and experience on countermeasures for damaged road reconstruction and rehabilitation, the Japan International Cooperation Agency (hereinafter, JICA) has decided to launch this survey.

1.2 Objectives

The JICA Survey Team (hereinafter, JST) will conduct this survey with the following four objectives:

1. Collect and analyze information on road landslides, currently used technologies, and institutional arrangements.
2. Clarify the various road landslide issues with respect to national and provincial roads,
3. Discuss appropriate and available countermeasures and introduce Japan's applicable countermeasures against road landslides.
4. Formulate the survey results for JICA's further cooperation with Pakistan.

1.3 Scope of the Project

1.3.1 Target Location

This survey's target area is the Himalaya Karakoram mountain chain in the northern part of Pakistan. More specifically, the project site consists of the national and provincial roads in following provinces:

- Khyber Pakhtunkhwa (KP) province
- The northern part of Punjab (PJ) province

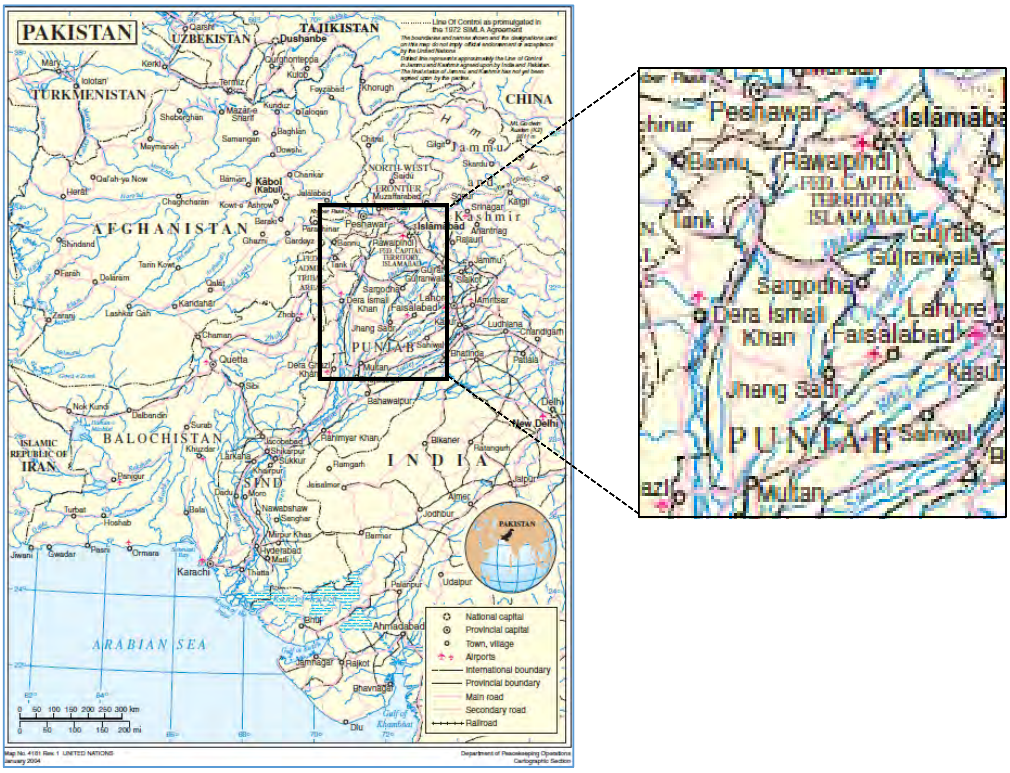


Figure 1.1 Project's Target Location

Source: JICA Survey Team

1.3.2 Target Organizations

The following organizations will be main target to obtain the necessary information.

- National Highway Authority (NHA)
- Communication & Works Department (C&W): PJ province, KP province

1.4 Method of Survey

The study policies and methods are shown in Table 1.1.

Table 1.1 Policies of Survey (1/2)

Study Policy	Study Method	Study Activities, Output
Promoting JICA cooperation approach	Promotion of understanding of applicable road disaster countermeasures in Pakistan	● Introduction of case study on low-cost road disaster countermeasures during rapid-growth period in Japan. ● Introduction on road disaster countermeasures in middle-income countries. ● Reporting to promote understanding of unimplemented road disaster countermeasures in Pakistan.
	Enhancement of backup system for recommendations of organization / operation of road disaster prevention administration	● Checked with Japanese prominent and experienced road disaster administration advisor. ● External support with vice chairman of the Landslide Society in Japan for exchange of technical information.
	Formulation for JICA's further cooperation	This study is the first JICA cooperation on road disasters in Pakistan, and the formulation may cover JICA technical cooperation, grand aid, and loan project.
	Donor cooperation	Exchanging of views with WB, ADB, UNDP.
	Suggestion based upon lessons learned	Summarize JICA and other donors' activities, and reflect them to next projects.
	Utilization with previous/existing information	● Information collection from NHA, C&W, and other related organizations with support from NHA and C&W. ● Data collection from national census statistics and relevant transport statistics. ● Geological data collection from Geological Survey in Pakistan.
Information collection and summary	Donors' output utilization	Exchange of views with ADB "Khyber Pakhtunkhwa Provincial Road Improvement Project."
		Exchange of views with UNDP "Field Manual on Slope Stabilization Project."
		Exchange of views with WB "Khyber Pakhtunkhwa Province Emergency Roads Recovery Project 2011."
	Implementation structure & budget	● Confirmation on employment plan for new engineers in NHA ● Confirmation on budget and expenditure for road construction, maintenance, and road landslide countermeasures in NHA
	Study on exiting guidelines	● Confirmation on formulation for guidelines on road slope stabilization with NHA and C&W. ● Introduction on Japan's road slope measures and slope protection guidelines (technical guidelines) for promoting Pakistan's formulation.
	Site observation	● Site observation for road disaster situation and its countermeasures.

Source: JICA Survey Team

Table 1.1Policies of Survey(2/2)

Study Policy	Study Method	Study Activities, Output
Road disaster risk analysis	Knowledge and data sharing with NHA and C&W	● Confirmation of NHA, C&W hazard map usability. ● Studying road infrastructure damage record through sharing with Frontier Works Organization (FWO) road clearance log.
	Risk analysis for regional economy	Studying through exchanging of views on road disaster vulnerability with NHA and C&W. Studying risk analysis with traffic volume, regional economy, detour routes, etc.
	Environmental and social considerations	Confirmation of NHA's environmental assessment for road development.
	Simplified road disaster evaluation	Prioritize road disaster countermeasure sites and methods with respect to the following three views.
		● Natural environment view: Prioritization of road disaster countermeasure sites through "simplified road disaster chart."
		● Social/economic view: Prioritization of road disaster countermeasure sites through national/provincial road economic impact.
		● Strategic view: Prioritization of road disaster countermeasure sites through donor activities.
Cooperation approach	Appreciation of Pakistan's needs and situation	Studying planning, budgeting, procurement, implementation, and competition processes by hearing from NHA and C&W.
	Proposing applicable road disaster countermeasures	Proposing for applicable road disaster countermeasures in mountainous region with slope damage risk, economy, workability, effectiveness, and cost. Several countermeasures may be proposed at each site. Through NHA, C&W, and JICA's comments, countermeasure methods may be finalized.
	Capacity development for NHA and C&W road disaster technical knowledge	Proposing capacity development ideas based upon related organization roles. Training program in Japan for developing capacity through site visiting and acquisition of required technical knowledge.

Source: JICA Survey Team

1.5 Survey Schedule

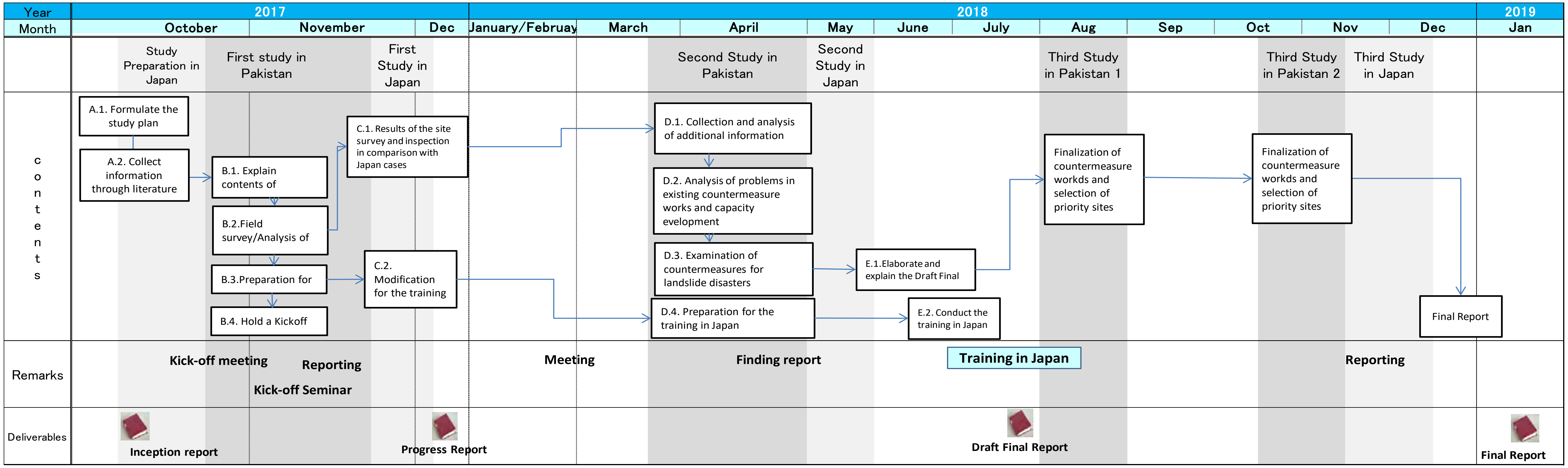


Figure 1.2 Task Flowchart Source: JICA Survey Team

1.6 Survey Output

1.6.1 Collect and analyze information on road landslides, currently used technologies, and institutional arrangements

The survey team collected and analyzed information on road landslides, proposed a NHA action strategy, and laid out an action plan to move forward on four issues.

In the past, the NHA has mostly employed “road clearance” and “reconstruction” as emergency responses; however, these countermeasures were found to be vulnerable.

Therefore, the survey team proposed a NHA action strategy titled “Shift from Emergency Response to Preparedness,” and recommended that the NHA apply resilient structure countermeasures against road landslide disasters, as shown in Figure 1.3.

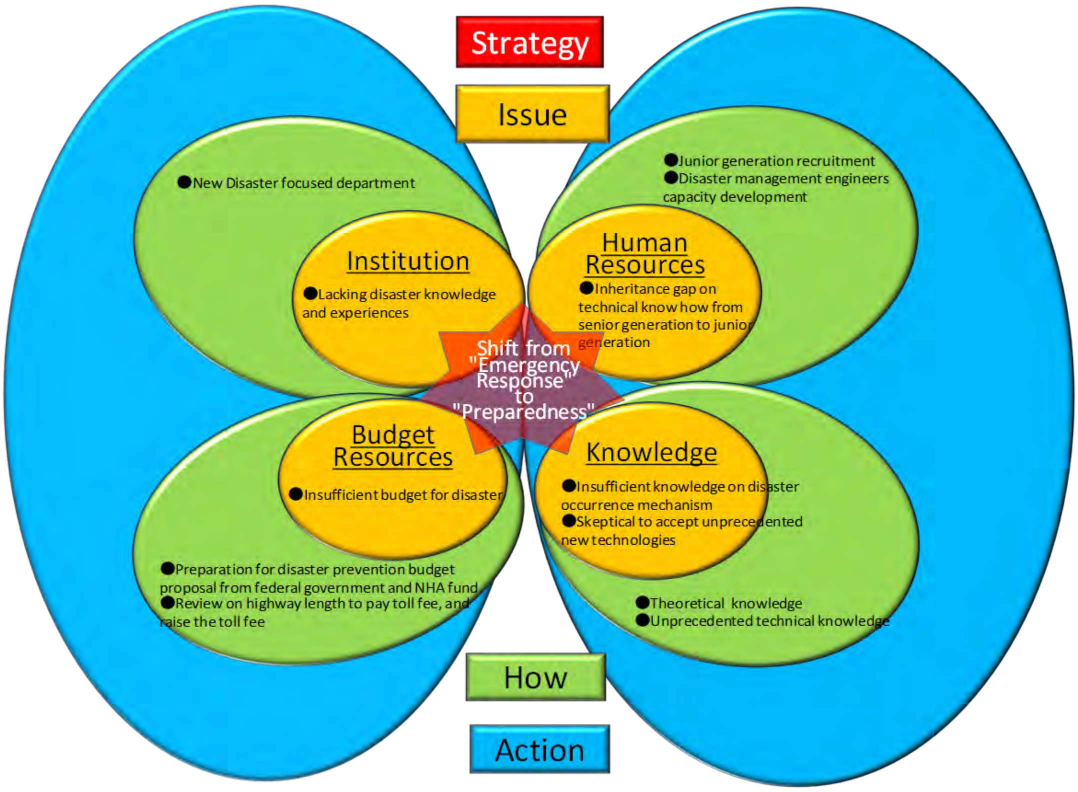


Figure 1.3 NHA action strategy

Based on the NHA action strategy, the essence of the current situation of the NHA, the problems it faces, and a plan of action to go forward are summarized in Table 1.2.

Table 1.2 NHA Current Situation, Problems and Actions to Go Forward

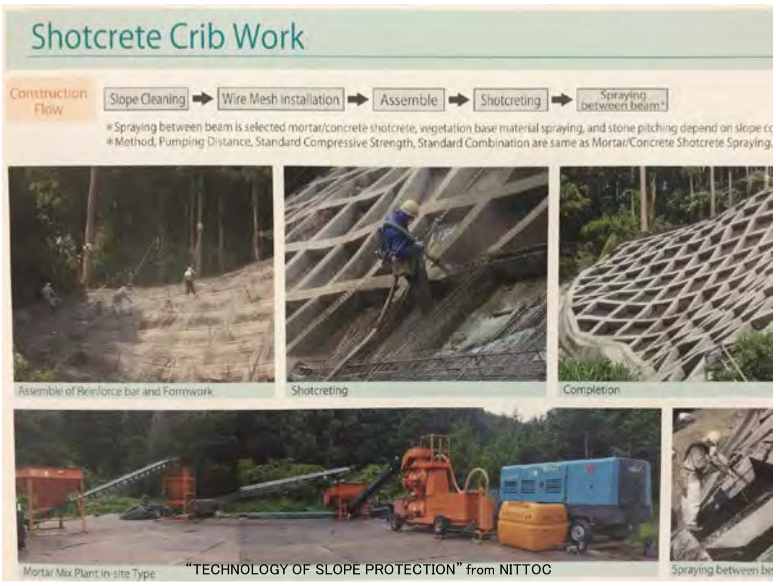
Issue	Current Situation	Problem	Action to Go Forward
Human Resources	The NHA has not recruited new staff since 2011, and the NHA staff are aging. The staff constitution by age is shifting from a stable pyramid with a large number of junior staff to an unstable bell with a large number of senior staff and fewer junior staffers. The small number of junior-generation staff at the regional office and maintenance unit may lead to an inheritance gap of technical know-how from the senior generation to the junior generation.	Inheritance gap of technical know-how from the senior generation to the junior generation.	Junior engineers should be assigned to disaster-prone regional offices.
Knowledge	Maintenance unit relies on a contracted consultancy, which drafts the technical reports for slope protection countermeasures.	Lack of investigation, analysis, and monitoring technology for landslide disasters for NHA engineers. RAMD has difficulties in proposing countermeasures employing new technology against the contracted consultancy, which proposes old design countermeasures.	NHA road administrators will be able to observe what types of countermeasure methods are effective, and to consider the construction method independently in the future by understanding the causes and mechanisms of landslides. It is necessary to transfer the new technology of investigation, analysis, and monitoring of landslides.
Institution	Historical disaster files are printed documents, which are unsystematically filed at NHA headquarters, regional offices, or maintenance units. Disaster prevention lessons and learnt have not been accumulated, since the NHA has not been any specific disaster prevention department, instead of road maintenance department.	Appraisal process of technical report relies mainly on individual knowledge and experiences, and thus the appraisal process should be carried out more efficiently.	To effectively accumulate knowledge and lessons on disaster prevention, a new "Disasters" department should be established at NHA headquarters.

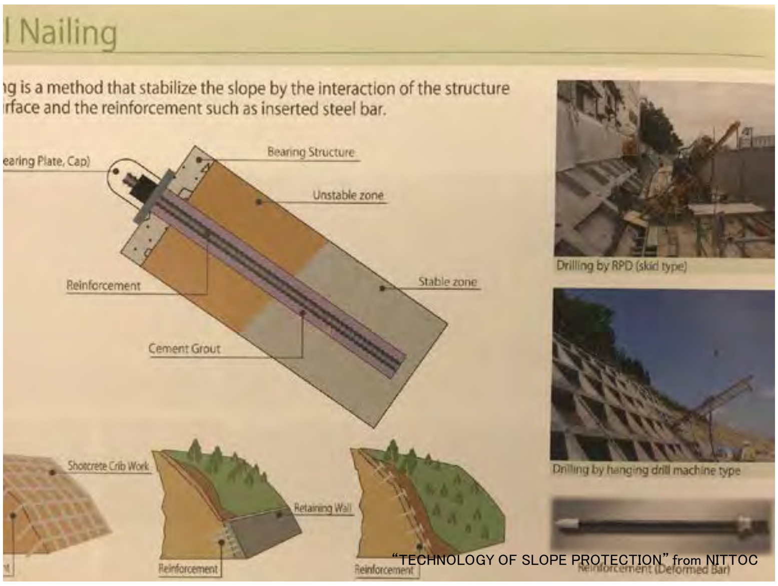
Budget Resources	The actual road maintenance budget generated through the road maintenance account 2009–2015 has been 33% to 59% lower than the unconstrained maintenance required, which has led to insufficient disaster prevention countermeasures.	The actual toll fee only covers a small section of the total highway length, and the toll fee is low, which is under NHA's responsibility. This is not sufficient for disaster prevention countermeasures.	Expand the disaster prevention budget from the federal government. Expand the section of the highway length subject to toll fees and increase the toll fee, so that road maintenance will be carried out properly.

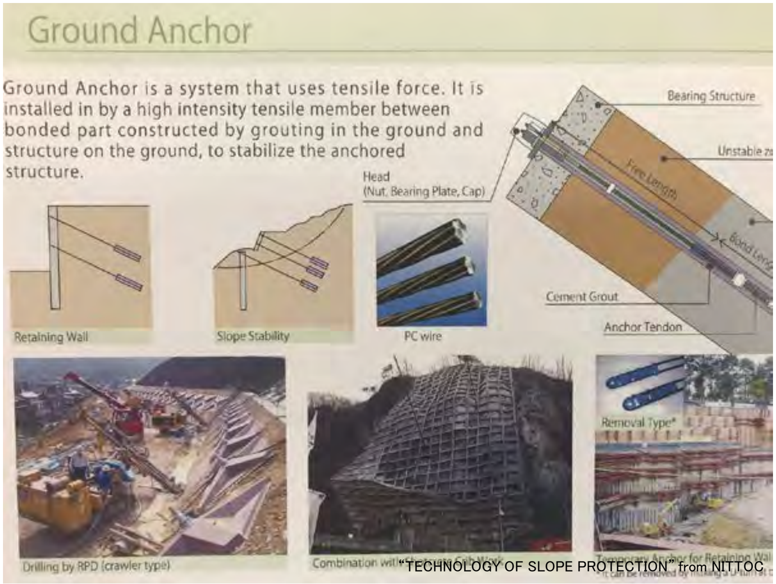
1.6.2 Clarify the various road landslide issues observed on national and provincial roads

The following road landslide disaster preventive methods can be differentiated from the other methods used in the site and are recommendable as shown below Table 1.3.

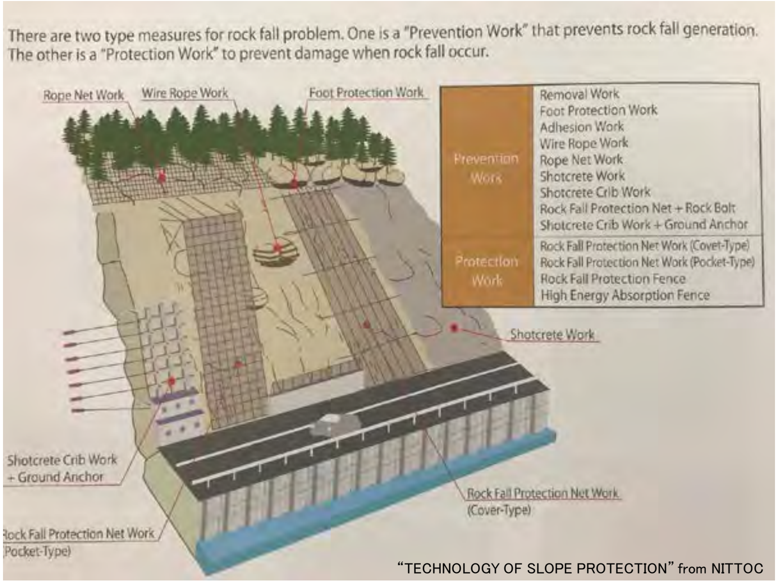
Table 1.3 Selected Countermeasure Methods

Method	Mortar/Concrete Shotcrete Spraying
Diagram	
Explanation	Mixture of continuous fiber (polystyrene) sand soil water is sprayed onto the unstable slope, forming a thick layer and unifying the slope and the continuous fiber-reinforced soil. It is usually adopted for mountain side cuttings to prevent erosion, weathering, and surface collapse.
Method	Shotcrete Crib Work
Diagram	
Explanation	Slope stabilization method in which the grid frame is installed on an unstable slope. Wire mesh grid is frequently used for a grid frame and can be divided into types: onsite installation or precast. This method can be combined with vegetation mats, shotcrete spraying, rockbolts, ground anchors, etc.

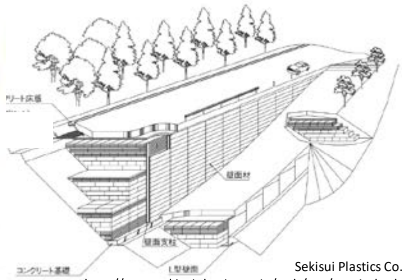
<table>
<tr><th>Method</th><th>Reinforced Earth Work/Rockbolt</th></tr>
<tr><td>Diagram</td><td>


"TECHNOLOGY OF SLOPE PROTECTION" from NITTOC
</td></tr>
<tr><td>Explanation</td><td>A steel bar (rockbolt) penetrates the stable ground along with mortar to stabilize the unstable slope by its tensile strength. Dynamically, the resistance force of the rockbolt restrains the force of the moving landmass. This method can be adopted at steep slopes (exceeding the stable gradient), which can also reduce the cutting volume and preserve the vegetation of the slope.</td></tr>
<tr><th>Method</th><th>Ground Anchor</th></tr>
<tr><td>Diagram</td><td>


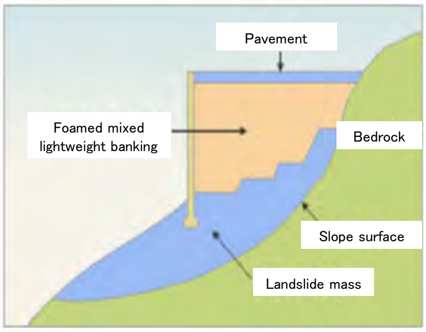
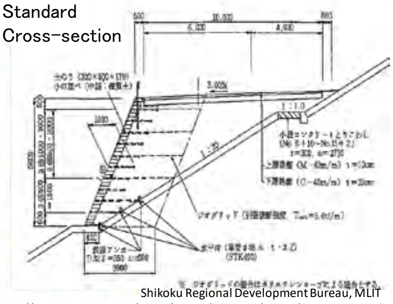
"TECHNOLOGY OF SLOPE PROTECTION" from NITTOC
</td></tr>
<tr><td>Explanation</td><td>A ground anchor stabilizes the slope by installing high-intensity pc wire, which has a large resistance force. The bonded part (anchored zone) constructed by grouting in the ground and the anchor tendon is fixed to the surface using the bearing plate. The tensile strength can be adjusted at the head of the ground anchor. Therefore, the safety factor (one of the concepts of quality performance indicators that compare the ratio of the moving force and the restraint force) of the slope can be managed artificially, depending on the situation. In addition, it is an innovative infrastructure technology as the shape and material of the bearing plate can be further developed.</td></tr>
</table>

<table>
<tr><th>Method</th><th>Rockfall Prevention/Protection Work</th></tr>
<tr><td>Diagram</td><td>


</td></tr>
<tr><td>Explanation</td><td>There are two countermeasures for rockfalls, which are [prevention work] that prevents rockfall generation (restrain the detached rock using shotcrete spraying and crib work, or using rock net), and [protection work] to prevent damage when rockfalls occur (prevent the rock from reaching the road). Based on the discussion with a Pakistani professor of geotechnical engineering, the concept of rockfall protection/prevention work is new in Pakistan. Therefore, the new method of rockfall protection work shall be introduced at the candidate site (N15_8).</td></tr>
<tr><th>Method</th><th>Lightweight Banking Method (Expanded Polystyrene, EPS)</th></tr>
<tr><td>Diagram</td><td>
EPS Method
(Expanded Poly-Styrene)
Hokukon Co.Ltd
https://www.hokukon.co.jp/catalog/data/ro/eps.pdf



Sekisui Plastics Co.Ltd
http://www.sekisuiplastics.co.jp/prdt/eps/eps_index.html
</td></tr>
<tr><td>Explanation</td><td>EPS is a method in which polystyrene is used in a civil engineering structure. Taking advantage of its characteristics (light weight, self-reliance, workability), this method can be adopted for embankments or backfilling of retaining walls/bridge foundations in soft ground or on a steep slope. There are two manufacturing methods for EPS, which are framing and injection[1].</td></tr>
</table>

[1] Civil Engineering Glossary (Japan Society of Civil Engineering)

Method	Lightweight Banking Method (Foamed Cement Banking, FCB)
Diagram	FCB Method (Foamed Cement Banking)  Foam created from the foam gun  During construction    http://www.fcb-ken.e-const.jp/fcbsetumei.html
Explanation	The foamed cement banking (FCB) method utilizes foamed cement [air-milk (air mortar)]. Owing to its characteristics (light weight, fluidity, and self-reliance), it can be adopted for the soft ground and embankments within landslides, embankments on steep slopes, backfilling of structures, and any other places where there are difficulties in using normal soil.
Method	Reinforced Earth Method
Diagram	Installation of geo grid  Installation of front wall  After construction  Standard Cross-section  Shikoku Regional Development Bureau, MLIT http://www.skr.mlit.go.jp/yongi/duties/research/douro/m_F-01_03.pdf
Explanation	The reinforced earth method stabilizes the earth structure by mixing reinforced material to increase the strength of the soil. Reinforced materials for embankments include steel material, geotextile, and mixed fiber, which are utilized in the backfilling of terre armee and embankments. These materials are reinforced for tensile, compress, shear, and bending. The internal stability (stability within the reinforcement range) and external stability (stability outside of the reinforcement range) shall be considered during the designing of the reinforced materials.

1.6.3 Discuss appropriate and available countermeasures and introduce Japan's applied countermeasures against road landslides

In Pakistan, the frequency of occurrence of natural disasters such as floods, earthquakes, landslide disasters, and cyclones is very high. In KP and Northern PJ, owing to harsh geographical conditions such as steep mountainous areas and the aforementioned frequent natural disasters, road infrastructure (which is the basis of economic activity) is severely damaged every year. No drastic structural countermeasures (infrastructural measures) have ever been implemented to protect the road infrastructure against landslide disasters, and technical measures (such as establishing traffic restrictions in advance) have also not been undertaken. Based on this context, the issues concerning landslide disaster countermeasures for Pakistan's national highways have been organized in this report, in addition to ideas on capacity development. The detailed discussion is presented in "5.3 Capacity Development of Road Landslides."

Table 1.4 Issues and Capacity Development Ideas

Issue	Capacity development
Lack of investigation, analysis, and monitoring technology for landslide disasters	Capacity development on investigation, analysis, and monitoring for landslide disasters
Master plan of road landslides countermeasures does not exist.	Capacity development on creation of master plan for road landslide countermeasures
Effective structural countermeasures (infrastructural measures) have not been implemented against these landslide disasters.	Capacity development on implementation of structural countermeasures for small to medium-scale landslide disasters
Technical measures, such as traffic restrictions in advance of landslide disaster, have not been established.	Capacity development on preparation of preliminary traffic regulation

1.6.4 Formulate survey results for JICA's further financial assistance to Pakistan

In order to select the high-propriety sites for JICA's further financial cooperation, three lists — the "Long list," "Middle list," and "Short list" — were prepared based on natural and social conditions.

Based on the slopes identified from topographical interpretation, relatively large-scale slopes have been selected to form a part of the [Candidate Slopes for Long list]. A "Simplified Slope Chart"[2] will be prepared for each listed slope based on the field survey. Part of the study area (N15: north of Naran, N35: north of Besham, N75: north of Murree, N45, N90, and N95), however, could not be accessed by the JST owing to safety reasons. Therefore, the field survey for this area was outsourced to Pakistani professors. The "Long list" was prepared considering the results of the field survey (Simplified Slope Chart) and the request raised by the NHA.

Table 1.5 Status of Covered Slopes for Long List

Road	Non restricted area		Restricted area	
	Plan	Actual	Plan	Actual
N 15	10	10	10	10
N 35	5	9	25	25
N 45	0	0	5	5
N 75	5	6	5	5
N 90	0	0	5	5
N 95	0	0	5	5
Total	**20**	**25**	**55**	**55**

The overall evaluation results of the 25 "Long List" sites located within the non restricted area for Japanese are as shown in the Table 1.5. A high overall evaluation means that the priority of implementation of landslide disaster countermeasure works is high. The sites with natural condition rank "A" were set as 11 sites of the "Middle List," as shown below in Table 1.6. Further details of the socioeconomical conditions in Table 1.6 are shown in Chapter 4.6.2.

[2] A compiled sheet that includes slope disaster location, disaster general information, location, pictures, etc. of each disaster location.

Table 1.6 Overall Evaluation Result as "Middle List" as "A"

Number	Types of diasaster	Natural Conditions Evaluation			Socioeconomical Conditions Evaluation					Comprehensive Evaluation	
		Hazaed Rank	Disaster History Rank	Disaster Scale Rank	Vehicle Operating Cost Rank	Alternative Road Rank	Connectivity Rank	Rank of constraints for route planning	Nearby Hospital Rank	Natural Conditions	Sosioeconomical Conditions
N15_1	Debris flow +Slope failure	b	b	c	2	2	2	1	1	B	8
N15_2	Slope failure	c	c	c	2	3	2	1	1	C	9
N15_3	Slope failure	a	a	a	2	3	2	2	2	A	11
N15_4	Slope failure +Rock fall	b	c	b	2	3	1	2	2	B	10
N15_5	Debris flow	a	a	a	1	3	1	3	3	A	11
N15_6	Slope failure	a	a	a	1	3	1	1	3	A	9
N15_7	Debris flow	c	c	c	1	1	3	1	3	C	9
N15_8	Rock fall	a	a	a	1	3	1	3	3	A	11
N15_9	Slope failure +Rock fall	a	a	a	1	3	1	2	3	A	10
N15_10	Debris flow	a	a	a	1	3	1	2	3	A	10
N35_1	Slope failure +Rock fall	b	b	a	3	3	1	2	1	A	10
N35_2	Slope failure +Rock fall	c	c	b	3	3	1	1	1	B	9
N35_3	Debris flow	c	b	c	3	3	1	2	2	B	11
N35_4	Debris flow	c	c	c	2	1	2	3	2	C	10
N35_5	Debris flow	c	b	c	2	2	2	2	3	B	11
N35_6	Slope failure	b	c	c	3	3	1	1	1	B	9
N35_7	Rock fall	b	b	b	2	2	1	2	3	B	10
N35_8	Rock fall	a	a	a	2	2	1	2	3	A	10
N35_9	Debris flow	a	a	b	2	1	2	3	3	A	11
N75_1_1	Slope failure +Debris flow	c	c	c	3	2	1	1	2	C	9
N75_1_2	Debris flow	c	c	c	3	2	1	1	2	C	9
N75_2	Slope failure	a	b	a	3	2	2	3	1	A	11
N75_3	Debris flow	c	c	c	3	2	2	1	1	C	9
N75_4	Debris flow	c	c	c	3	1	2	1	1	C	8
N75_5	Slope failure +Rock fall	a	b	a	3	2	2	2	1	A	10

From the 11 sites on the “Middle List,” the following six criteria were considered to select six sites for the “Short List” to determine where to implement countermeasures preferentially on the premise of financial cooperation, as shown in Table 1.7.

- Overall evaluation of natural conditions is “A.”
- Overall evaluation of socioeconomic conditions is “9” or more.
- Exclude Chinese project construction sections.
- Relative difficulty of design is “high” (from the survey and design stage, considerable technical support from the Japanese side is required).
- Construction systems is “A: Implemented by Japanese companies, providing technical guidance for local companies that would work as local contractors.”
- Slope countermeasure structures are being planned (excluding N15_5 countermeasures of debris flow “bridge”).

Table 1.7 “Short List”

National Road and Site Number	Current Situation
N15_3	Slope failure
N15_6	Slope failure
N15_8	Rockfall
N15_9	Slope failure + Rockfall
N75_2	Slope failure
N75_5	Slope failure + Rockfall

The following tables show lists of the countermeasure works at each “Short List” site.

Table 1.8 List of Countermeasure Works in N15

Slope	Side	Length	Numbering	Works	Units	Quantity
N15_3	Mountain	L=300m	N-15 No.3-①	Slope Cutting Works	㎡	339,000
			N-15 No.3-②	Framing Works	Sections	3,750
			N-15 No.3-③	Rockbolt Works	Units	750
			N-15 No.3-④	Mortar Spraying Works	㎡	11,100
			N-15 No.3-⑤	Gravity Retaining Wall Works	m	300
			N-15 No.3-⑥	Ground Anchoring Works	Units	3,000
			N-15 No.3-⑦	Drainage Works	m	300
	Valley	L=320m	N-15 No.3-⑧	Drainage Works (Pipe φ75)	Points	2,240
			N-15 No.3-⑨	Revetment Works	㎡	6,720
			N-15 No.3-⑩	Pavement Works $ Soil Improvement Works（Basecourse)	㎡	2,336
			N-15 No.3-⑪	Culvert Works and its Connecting Drainage	㎡	20
	Temporary Works to facilitate to implement above works				set	1
	Total in whole slope					

Slope	Side	Length	Numbering	Works	Units	Quantity
N15_6	Mountain	L=320m	N-15 No.6-①	Slope Cutting Works	㎡	224,000
			N-15 No.6-②	Framing Works	Sections	4,000
			N-15 No.6-③	Mortar Spraying Works	㎡	8,480
			N-15 No.6-④	Gravity Retaining Wall Works	m	320
			N-15 No.6-⑤	Ground Anchoring Works	Units	800
			N-15 No.6-⑥	Rockbolt Works	units	3,200
			N-15 No.6-⑦	Drainage Works	m	320
			N-15 No.6-⑧	Horizontal Drainage Boring to reduce ground water	m	9,000
	Valley	L=380m	N-15 No.6-⑨	Gabion Works	m	320
			N-15 No.6-⑩	Light Weight Banking (e.g. EPS, H=10.0m)	㎡	45,600
			N-15 No.6-⑪	Pavement Works $ Soil Improvement Works（Basecourse)	㎡	2,774
			N-15 No.6-⑫	Culvert Works and its Connecting Drainage	m	20
	Temporary Works to facilitate to implement above works				set	1
	Total in whole slope					

Slope	Side	Length	Numbering	Works	Units	Quantity
N15_8	Mountain	L=330m	N-15 No.8-①	Special Gravity Retaining Wall (Material/Expandable Bags)	m	330
				Special Gravity Retaining Wall (Installation Works)	Sets	1
				Special Gravity Retaining Wall (Transportation Fee)	Sets	1
	Valley	L=300m	N-15 No.8-②	Slope Cutting Works	㎡	27,000
			N-15 No.8-③	Mortar Spraying Works	Section	3,750
			N-15 No.8-④	Rockbolt Works	Units	3,750
			N-15 No.8-⑤	Gabion Works	m	300
			N-15 No.8-⑥	Pavement Works $ Soil Improvement Works（Basecourse)	㎡	2,409
			N-15 No.8-⑦	Culvert Works and its Connecting Drainage	m	300
			N-15 No.8-⑧	Drainage Works	m	300
	Temporary Works to facilitate to implement above works				set	1
	Total in whole slope					

N15_9	Mountain	L=130m	N-15 No.9-①	Slope Cutting Works	㎥	87,100
			N-15 No.9-②	Framing Works	Section	3,250
			N-15 No.9-④	Ground Anchoring Works	本	650
			N-15 No.9-⑤	Rockbolt Works	本	2,600
			N-15 No.9-⑥	Gravity Retaining Wall Works	m	300
			N-15 No.9-⑦	Drainage Works	m	300
	Valley	L=300m	N-15 No.9-⑧	Pavement Works $ Soil Improvement Works（Basecourse)	㎡	2,190
			N-15 No.9-⑨	Culvert Works and its Connecting Drainage	㎡	20
	Temporary Works to facilitate to implement above works					
	Total in whole slope				m	

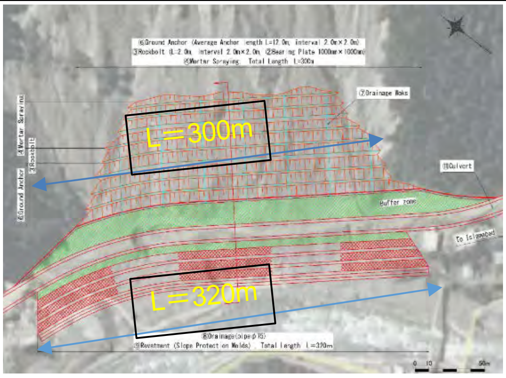
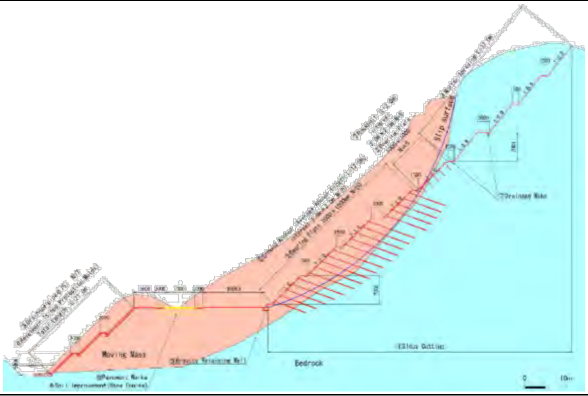
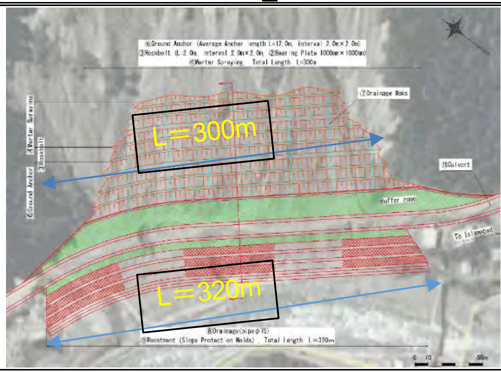
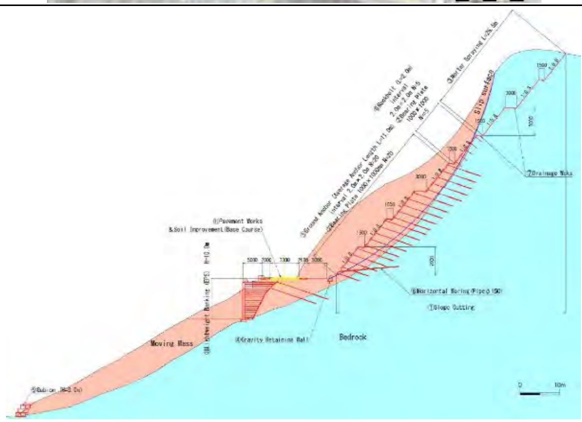
Table 1.9 List of Countermeasure Works in N75

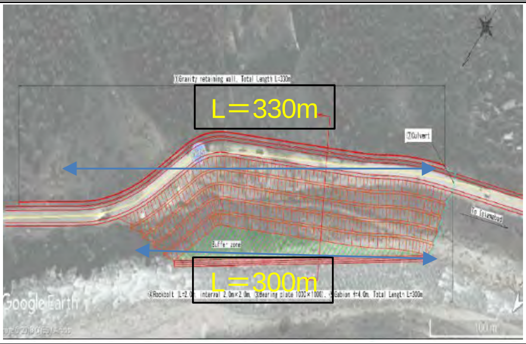
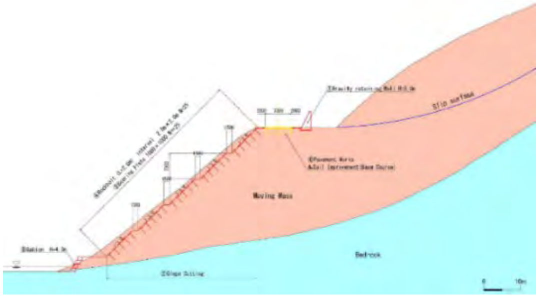
N75_2	Mountain	L=160m	N-75 No2-①	Slope Cutting Works	㎥	55,200
			N-75 No2-②	Framing Works	Section	800
			N-75 No2-③	Mortar Spraying Works	㎡	7,040
			N-75 No2-④	Rockbolt Works	Units	800
			N-75 No2-⑤	Gravity Retaining Wall Works	m	160
			N-75 No2-⑥	Drainage Works	m	160
			N-75 No2-⑦	Horizontal Dranage Boring to reduce ground water	m	32,000
	Valley	L=160m	N-75 No2-⑧	Earth Reinforced Works (e.g. Geotextile)	㎥	48,000
			N-75 No2-⑨	Drainage Works	m	160
			N-75 No2-⑩	Pavement Works $ Soil Improvement Works（Basecourse)	㎡	2,336
			N-75 No2-⑪	Culvert Works and its Connecting Drainage		40
	Temporary Works to facilitate to implement above works					
	Total in whole slope					

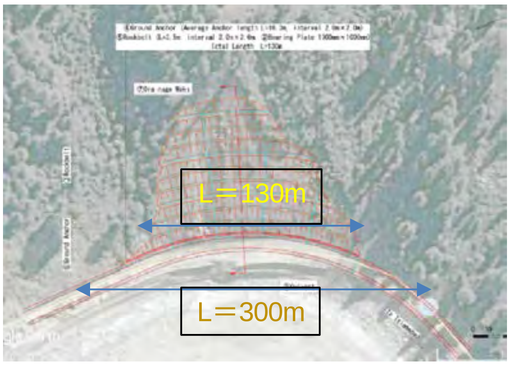
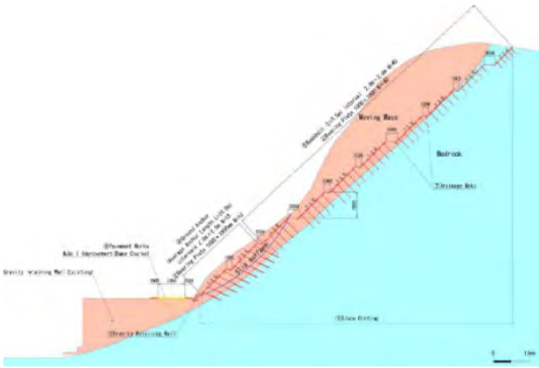
Slope	Side	Length	Numbering	Works	Units	Quantity
N75_5	Mountain	L=220m	N-75 No5-①	Slope Cutting Works	㎥	48,400
			N-75 No5-②	Countinous Fivber Spraying Works	㎡	10,120
			N-75 No5-③	Drainage Works	m	220
	Valley	L=180m	N-75 No5-④	Light Weight Banking (e.g. EPS, H=16.5m)	㎥	18,000
			N-75 No5-⑤	Pavement Works $ Soil Improvement Works（Basecourse)	㎡	2,628
			N-75 No5-⑥	Culvert Works and its Connecting Drainage	m	40
	Temporary Works to facilitate to implement above works				set	1
	Total in whole slope					

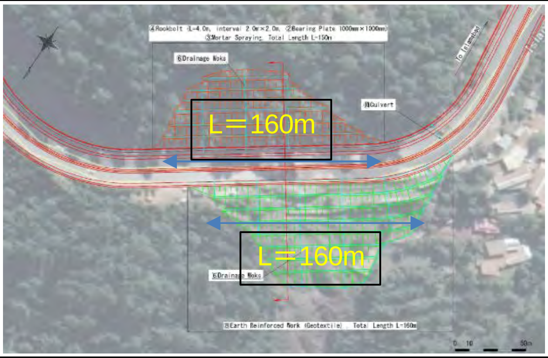
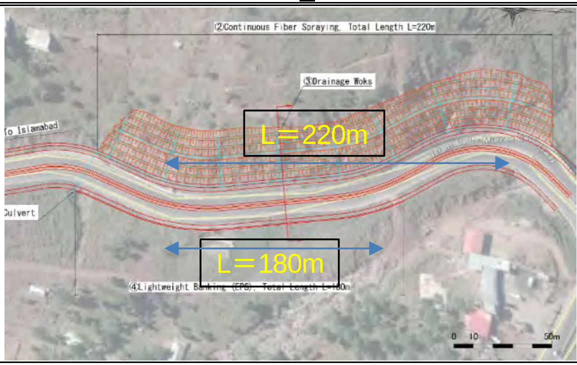
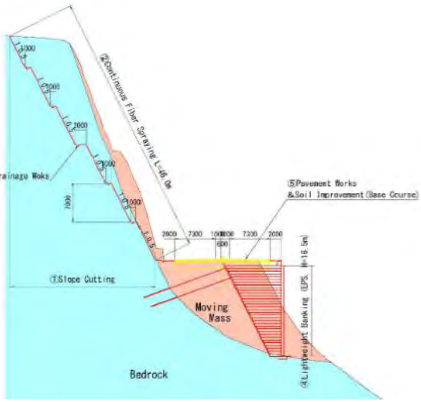
The following are shown as possible countermeasure works at each “Short List” slope.

Table 1.10 Possible Countermeasure Works at the Short List Slopes

Slope		N15_3
Plan View		
Typical cross-section		
Methods	Mountain	Crib work, rockbolt, shotcrete spray, retaining wall, ground anchor
	Valley	Revetment work, road pavement (soil improvement)
Slope		**N15_6**
Plan view		
Typical cross-section		
Methods	Mountain	Crib work, rockbolt, shotcrete spray, ground anchor
	Valley	Gabion, retaining wall, lightweight banking (eps), road pavement (soil improvement)

Slope		N15_8
Plan view		
Typical cross-section		
Methods	Mountain	Gravity-type retaining wall
	Valley	Crib work, rockbolt, gabion, road pavement (soil improvement)

Slope		N15_9
Plan view		
Typical cross-section		
Methods	Mountain	Crib work, shotcrete spray, rockbolt, retaining wall
	Valley	Crib work, ground anchor, rockbolt, road pavement (soil improvement), retaining wall

<table>
<tr><th colspan="2">Slope</th><th>N75_2</th></tr>
<tr><td colspan="2">Plan view</td><td>
</td></tr>
<tr><td colspan="2">Typical cross-section</td><td></td></tr>
<tr><td rowspan="2">Methods</td><td>Mountain</td><td>Crib work, shotcrete spray, rockbolt, retaining wall</td></tr>
<tr><td>Valley</td><td>Embankment reinforced earth method (geotextile), road pavement (soil improvement)</td></tr>
<tr><th colspan="2">Slope</th><th>N75_5</th></tr>
<tr><td colspan="2">Plan view</td><td>
</td></tr>
<tr><td colspan="2">Typical cross-section</td><td>
</td></tr>
<tr><td rowspan="2">Methods</td><td>Mountain</td><td>Continuous fiber spray</td></tr>
<tr><td>Valley</td><td>Lightweight banking (EPS), road pavement (soil improvement)</td></tr>
</table>

2 Information of Related Organizations

2.1 Related Upstream Policies

The related upstream policies of road maintenance, including road construction and landslide disasters, are Vision 2025 and the Public Sector Development Program (PSDP). Vision 2025 is a long-term strategy for the development and growth of Pakistan. PSDP is the annual development program implementation strategy and annual implementation project summary to accomplish the policy of Vision 2025.

2.1.1 Outline of Vision 2025

Vision 2025, enacted in 2014 May under the Ministry of Planning, Development and Reform, is a national development strategic plan formulated to pursue seven pillars or priority areas, as shown below, aiming for the economic development of Pakistan by the target year of 2025 and achieving the status of a high-income nation by 2047. Vision 2025 is periodically reviewed and updated by the Prime Minister and its strategic plan is being promoted. The Ministry of Planning, Development and Reform is the upper organization of the Ministry of Communication, which is responsible for the NHA, the counterpart of the survey.

I. Putting People First: Developing Human and Social Capital,

II. Achieving Sustained, Indigenous, and Inclusive Growth,

III. Democratic Governance, Institutional Reform, and Modernization of the Public Sector,

IV. Water, Energy, and Food Security,

V. Private Sector and Entrepreneurship-Led Growth,

VI. Developing a Competitive Knowledge Economy through Value Addition, and

VII. Modernization of Transportation Infrastructure and Greater Regional Connectivity.

This survey is related to Pillar VII, the target of which is to “to contribute approximately 10% to GDP growth and over 6% increase in employment through the reduction of transportation costs, safety, effective and rapid connectivity between rural and urban areas, and strengthening of transportation capacity for marketing city connectivity.” The detailed key targets of Pillar VII are as follows: “Road transportation represents the backbone of Pakistan’s transportation system, accounting for 96% of all passenger and freight traffic in the country confirming the importance of future roads. The target of the road sector is to increase the road density from 32 km/100 km^2 to 62 km/100 km^2, expanding the existing national road network from approximately 260,000 km to 358,000 km.”

The following concrete measure is proposed for the expansion of road network: “promote the utilization of a variety of financing and ownership mechanisms, such as Public–Private Partnerships (PPP) and Build-Operate-Transfer (BOT), owing to the limitations of the federal government’s own resources.”

The basic policy for realization of regional connectivity is the cooperation of the following organizations:

- China-Pakistan Economic Corridor (CPEC)[3], which will implement a road corridor plan connecting to a road in the China-Indian Ocean,
- South Asian Association for Regional Cooperation (SAARC),
- Central Asia Regional Economic Cooperation (CAREC),
- Economic Cooperation Organization (ECO).

These regional countries, organizations, and corridors are partially related to the landslide-prone northern region of Pakistan.

2.1.2 Outline of Public Sector Development Program (PSDP)

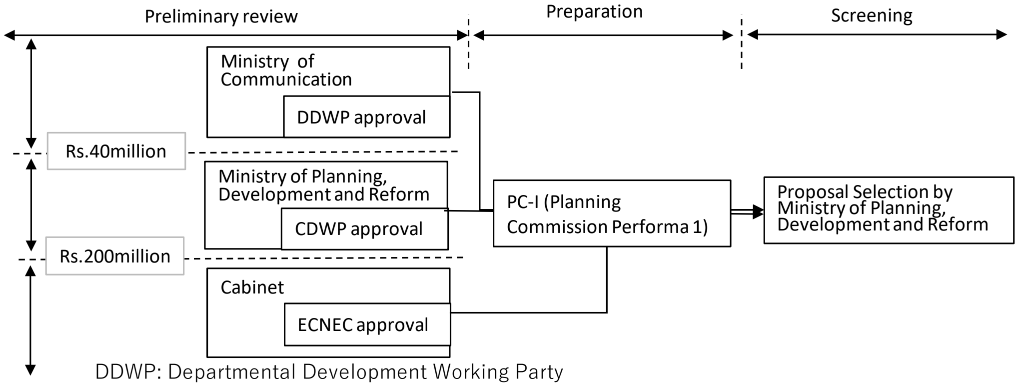
The Outline of Public Sector Development Program (PSDP) is a program that summarized the projects to be implemented every year based on the short-term microeconomic analysis and industrial sector development strategies, to accomplish the seven pillars of Vision 2025, toward the promotion of economic development. PSDP is updated annually by the Ministry of Planning, Development and Reform. The policy of one of the seven pillars of PSDP, Pillar VII “Modernization of Transportation Infrastructure,” highlights road construction projects; however, it does not mention any landslide disasters measures.

The total program budget of PSDP for FY2017 is Rs. 2,113 billion, of which Rs. 1,001 billion is for federal government development programs including NHA, and Rs. 1,112 billion is for state government development programs. Regarding the PSDP road construction budgets from the planning through approval process, the preliminary review process differs depending on the amount of the draft budgets, as shown in Figure 2.1.

In the preliminary review process, the NHA staff, under the Member of Planning, first formulate a draft development plan for the preliminary review. Then, the plans are classified as less than Rs.40 million, between Rs.40 million and Rs.200 million, and more than Rs.200 million. Each plan is reviewed respectively by the Department Development Working Party (DDWP), under the Ministry of Communications, which is responsible for NHA; the Central Development Working Party (CDWP), presided over by the planning committee vice chairman of the Ministry of Planning, Development and Reform; and the Executive Committee of National Economic Council (ECNEC).

The plan, approved during preliminary review, is developed as a proposal called PC-1 (Planning Commission Performa One) that includes the design and cost estimation by NHA Member of Planning with the collaboration of related divisions in NHA, and it is submitted to the Ministry of Planning, Development and Reform. The Ministry of Planning, Development and Reform conducts an appraisal while coordinating with the proposed development plans submitted by other ministries.

[3] Details explained in Chapter 3.5



DDWP: Departmental Development Working Party
CDWP: Central Development Working Party
ECNEC: Executive Committee of National Council
Source: Survey team study

Figure 2.1 Process from Preliminary Review to Screening

2.2 National Highway Authority (NHA)

2.2.1 NHA in General

The National Highway Authority (NHA) was created in 1991 for the planning, development, operation, repair, and maintenance of national roads, highways, motor ways[4], and strategic roads in Pakistan. The NHA is entrusted with 39 national roads, motorways, highways, and strategic roads with a total length of 12,131 km, as shown in Table 2.1 and Table 2.2.

This is 4.6% of the total national road network, i.e., 261,595 km, which carries 80% of passenger traffic[5] and 65% of freight traffic[6].

Table 2.1 Types of Roads Managed by NHA

Type of Road	Road Length (km)
National Roads	9,489
Motorways	2,280
Expressways	100
Strategic Roads	262
NHA total roads	12,131

Source: NHA Annual Maintenance Plan FY2016–17

Table 2.2 Road Length by Province

Province	Road Length(km)
PJ (Punjab)	2,731
Sindh	2,204
KP (Khyber Pakhtunkhwa)	1,888
Balochistan	4,565
Others	753

Source: NHA Annual Maintenance Plan FY2016–17

The NHA road map and target area of this survey is shown in Figure 2.2. National roads and strategic roads are hereinafter named as N-# and S-#, respectively.

[4] Highway: road for vehicles with speed limit exceeding 100km/h and has longer interval of the exit lamp. Motorway: road for vehicles with speed limit exceeding 100km/h. National Highway: road maintained by NHA (accessible for pedestrians)
[5] Unit of passenger traffic is “km-man”
[6] Unit of freight traffic is “km-ton”

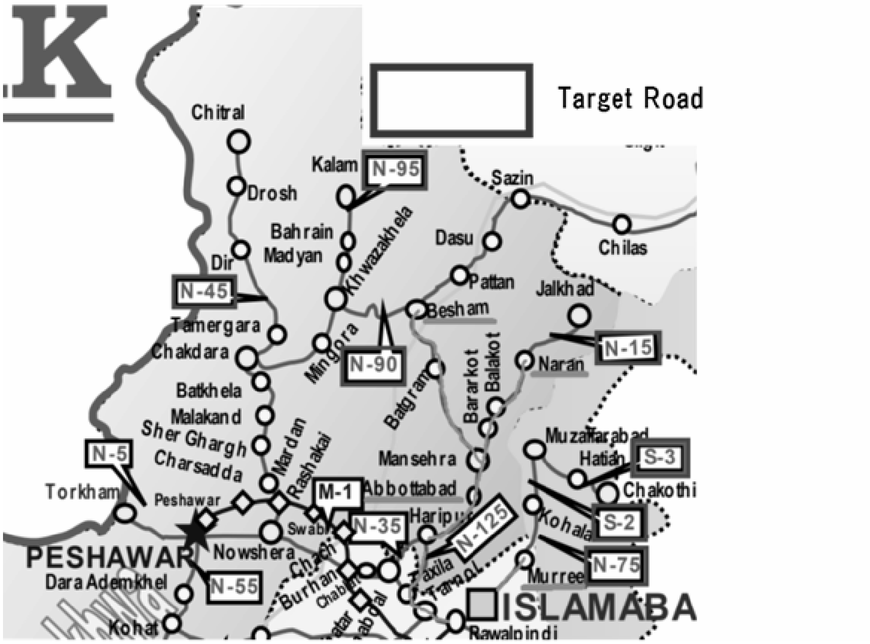


Figure 2.2 Road Network of NHA within Survey Area Source: NHA Webpage

2.2.2 NHA Five-year Development Plan 2018–2023

The NHA five-year development plan is mainly divided into a core-development program focused on international, regional, and strategic connectivity, and a sub-development program focused on safe roads in provincial areas. The budget ratio between the core-development and sub-development programs is 80:20. Regarding provincial roads, the main focus is connectivity between states and cities.

The NHA has been constructing roads following their drafted five-year development plan (2012–2017) under the PSDP strategy. The NHA five-year development plan (2018–2023) will take over the projects that could not be implemented in the previous five-year development plan. To accomplish this in the five-year road construction projects along the PSDP strategy, the NHA Member of Planning drafted a five-year development plan. A five-year development plan (2018–2023) for the construction of new roads along the PSDP was approved by the NHA Executive Board meeting No. 271 on December 21, 2016. Eighty-four road construction projects with an estimated cost of Rs. 1,059 billion are planned to be completed within this five-year period. In terms of the approval process of the NHA for the five-year development plan (2018–2023), the draft of the five-year development plan was first submitted by the Member of Planning to the NHA Executive Board, following whose approval, the plan was submitted to the Ministry of Planning, Development and Reform for further selection.

The outcome of this five-year development plan (2018–23) in terms of construction of roads, bridges, and tunnels will be the following: Construction of highways, 5,196 km; motor ways, 1,300 km; major bridges, 36; and tunnels, 7. The prioritization of construction of roads, bridges, and tunnels has a strong political influence according to the interview with NHA engineers. However, road maintenance projects are not planned in the five-year development plan, which is full of road construction projects.

2.2.3 NHA Road Operation and Maintenance Plan (2016–2017)

The NHA annual maintenance plan accumulates all the planned implementation projects for road maintenance of each year and it is drafted by the Road Asset Management Division (hereinafter, RAMD). The NHA Executive Board meeting No. 273 approved the annual maintenance plan for 2016–2017 on January 30, 2017. The total maintenance budget for 2016–2017 is Rs. 38,559 million, and the detailed annual plan includes routine/periodic maintenance and rehabilitation work for all regions.

The annual road maintenance budget (routine maintenance, periodic maintenance, and rehabilitation) for 2016–2017 was Rs. 17,696 million (45%), which was estimated by the Highway Development and Management System (HDM-4). Rs. 6,065 million (16%) is for unforeseeable budget (emergencies, detour, bridge, maintenance, etc.,) and Rs. 14,798 million (38%) is for other unpaid budget from the previous year.

Table 2.3 shows the road maintenance budget by each regional office for 2016–2017.

Table 2.4 shows the routine maintenance budget (2016–2017) of the Abbottabad and Balakot maintenance unit (Northern Area), which is related to this survey. The budget is estimated by multiplying unit price for routine inspection (per km) and estimated length.

Unforeseeable budget such as emergencies, re-routing, and bridge maintenance budget is managed by NHA headquarters. Once a landslide occurs, the regional office proposes the required budget to NHA headquarters, and then NHA headquarters proceeds with the technical aspects and administrative approval of the request. Therefore, no budget is planned by the regional offices.

Table 2.3 Maintenance Budget (2016–2017) by Each Regional Office (Unit: Rs. Million)

	Punjab North	Punjab South	Sindh North	Sindh South	**Khyber Pakhtunkhwa**	Balochistan North	Balochistan South	Balochistan Wet Makran	**Northern Areas**	Gilgit-Baltistan	Muzaffarabad	M'way	Total
Routine Maintenance	294.75	610.17	503.70	447.28	743.46	980.87	204.94	100.62	279.97	252.48	101.85	210.28	4,730.37
Periodic Maintenance (Functional Overlay)	546.62	256.10	579.58	283.05	288.66	404.36	256.10	417.84	377.40	202.18	489.00	646.98	4,747.87
Periodic Maintenance (Structural Overlay)	901.11	1,682.64	801.04	209.20	1,024.39	1,313.22							5,931.60
Rehabilitation	850.00			426.71								58.72	1,335.43
Highway Safety				150.00								801.11	951.11
Total													17,696.38

*Regional offices related to this survey is in bold
Source: NHA Annual Maintenance Plan FY2016–17

Table 2.4 Routine Maintenance Budget (2016–1017) for Abbottabad and Balakot Maintenance Units

Abbottabad Maintenance Unit

Route		km	km	Length (km)	Amount (Rs. Million)
1	N-35	0+00	30+00	30.00	13.143
2	N-35	30+00	50+00	20.00	14.169
3	N-35	50+00	70+00	20.00	14.046
4	N-35	70+00	100+00	30.00	13.852
5	N-35	100+00	130+00	30.00	10.283
6	N-35	130+00	150+00	20.00	13.083
7	N-35	150+00	190+00	40.00	12.184
Sub Total N-35				190.00	90.760
8	N-125	0+00	20+00	20.00	10.836
9	N-125	20+00	44+00	24.00	10.160

Sub Total N-125				44.00	20.996
Sub Total Abbottabad				234.00	111.756
Balakot Maintenance Unit					
10	N-15	0+00	20+00	20.00	7.615
11	N-15	20+00	40+00	20.00	8.728
12	N-15	40+00	60+00	20.00	8.866
13	N-15	60+00	80+00	20.00	11.252
14	N-15	80+00	100+00	20.00	9.696
15	N-15	100+00	123+00	23.00	10.923
16	N-15	123+00	142+00	19.00	10.239
17	N-15	142+00	162+00	20.00	10.438
18	N-15	162+00	175+00	13.00	8.553
19	N-15	175+00	191+00	16.00	8.553
20	N-15	191+00	210+00	19.00	7.877
21	N-15	210+00	234+00	24.00	7.877
Sub Total N-15				234.00	110.617
Grand Total Balakot				234.00	110.617
Grand Total Northern Area				468.00	222.373
FWO Routine Maintenance (N-35, 191–350)				120.00	57.600
Grand Total Northern Area					279.973

Source: NHA Annual Maintenance Plan FY2016–17

2.2.4 Organization

The NHA headquarters and zonal office organization chart is shown in Figure 2.3. The Finance, Administration, Planning, Technical, and Coordination (hereinafter, Engineering Coordination) Members are in NHA headquarters. In the zonal office organization, there are four regional offices and two motorway offices in each zone.

The following General Managers (GMs) are under the Member of Planning:

- GM Planning is responsible to sum up all the NHA budget requests for road construction and road maintenance to PSDP, and to request all NHA budget from PSDP.
- GM Design is responsible to approve the design of new construction projects; GM RAMD is responsible for the preparation of the Annual Maintenance Plan (AMP) for each year and managing and administering maintenance works accordingly.

The following GMs are under the Member of Engineering Coordination;

- GM Construction is responsible for the management of new construction works.
- GM PPP/BOT is responsible to promote the introduction of public–private partnerships.
- GM (P&CA: Procurement & Contract Administration) is responsible to procure contractors for construction and consultants for surveying, design, and construction supervision services.

The four zonal offices are responsible to design, construct, supervise, and maintain their individual projects. The motorway offices are responsible to design, construct, and supervise their projects, but they do not conduct maintenance work.

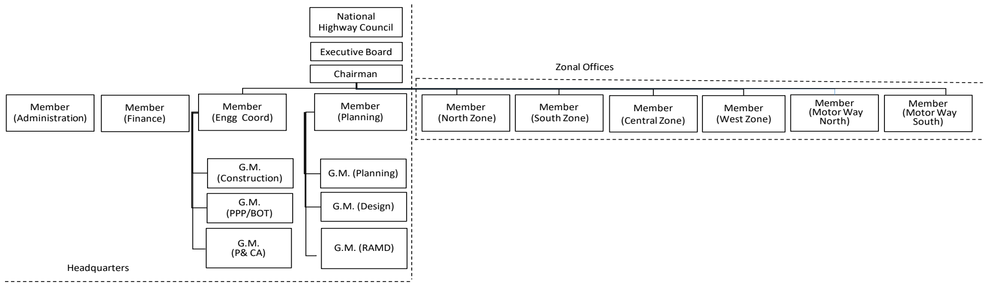


Figure 2.3 Headquarters and Zonal Offices of NHA Source: JICA Survey Team

a. Executive Board of NHA

The NHA Executive Board approves the NHA's business policy, operation policy, etc. There are nine members, as shown in Table 2.5, and the board meetings are held at least once every three months.

Table 2.5 Members of Executive Board of NHA Source: NHA Webpage)

Title	Title in Executive Board
Chairman, NHA	Chairman
Inspector General, National Highways & Pakistan Motorway Police	Member
Additional Secretary (Finance)	Member
Member or Additional Secretary Planning & Development Division	Member
Joint Secretary (II), Ministry of Communications	Member
Senior Chief National Transport Research Center	Member
Vice President, NESPAK	Member
Member (Finance), NHA	Member
Member (Planning), NHA	Member

The main roles of the Executive Board are as follows:

- Appraisal and approval of projects over Rs. 100 million,
- Approval of five-year development plan and annual maintenance plan,
- Approval of projects funded by the road maintenance fund.

b. NHA Organization Related to Road Operation and Maintenance

The NHA road operation and maintenance organization related to this survey is shown Figure 2.4. The division in charge of road operation and maintenance in NHA headquarters is RAMD, which consists of the GM (RAMD), Director (RAMS), and Deputy Director (Structures, RAMS, System Analyst, and Surveys), as shown in Table 2.4.

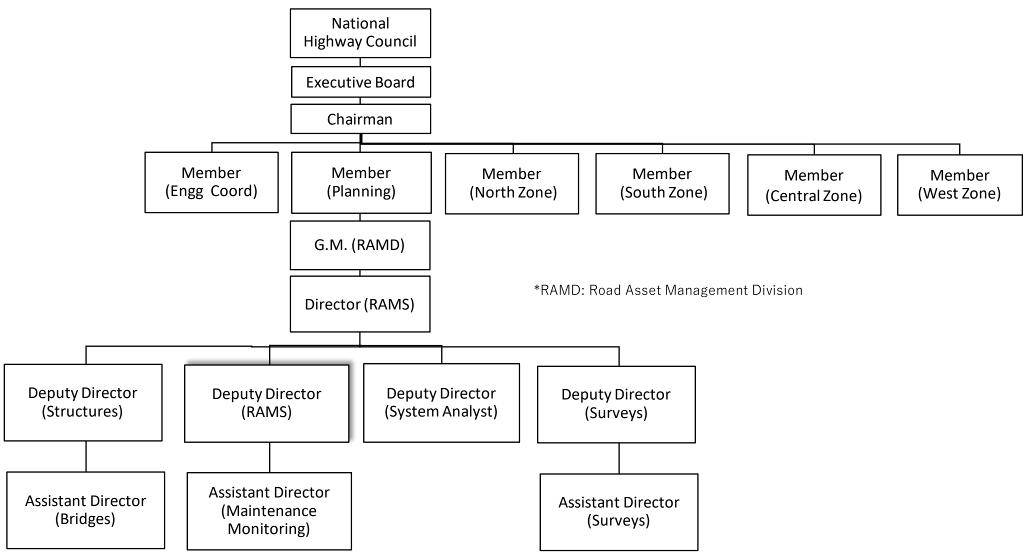


Figure 2.4 NHA Organization Related to Road Operation and Maintenance
Source: JICA Survey Team

NHA headquarters is responsible for planning the road maintenance budget, and providing technical support to regional offices to conduct road maintenance works. Moreover, the regional offices are responsible for the road maintenance of each site.

Figure 2.5 shows the organogram of the entire regions (zones) of NHA related to road maintenance (zonal offices and regional offices of road construction and general affairs are omitted in Figure 2.5.). Four Members of the zonal offices and Members of Engineer and Coordination in NHA headquarters are responsible for road maintenance. Under each of the four zonal offices, 2–4 regional offices are subdivided.

Road N-75 is also called the Islamabad Murree Dual Carriageway (IMDC), located in the northern part of Punjab Province and originally belongs to the Member Central Zone, GM Punjab North. However, N-75 is close to the capital and the government recognized N-75 as important functioning road; thus, N-75 is a special case managed by the Members of Engineering and Coordination at NHA headquarters.

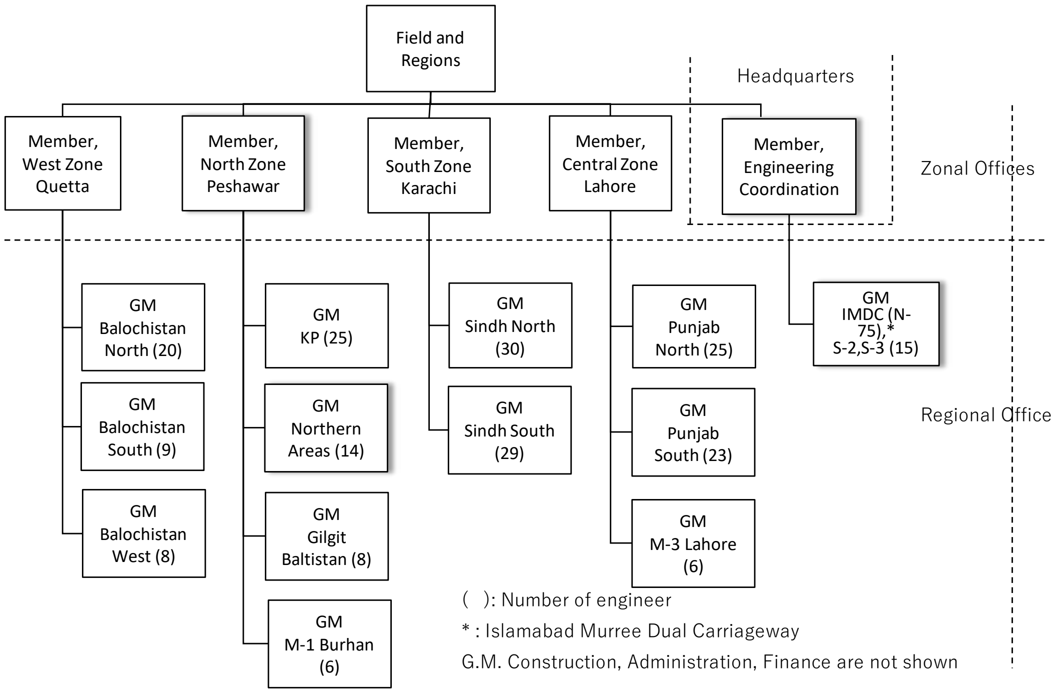


Figure 2.5 NHA Zonal Offices and Regional Office

Source: JICA Survey Team

The survey area is under responsibility of Member North Zone and Member Engineering Coordination. The non restricted area for the Japanese Survey Team (JST), which is under the responsibility of GM IMDC (N-75), and the GM Northern Area, which is responsible for N-15 and N-35, are shown in Figure 2.6.

The Murree Maintenance Unit and Muzaffarabad Maintenance Unit are under the Maintenance Director in GM IMDC (N-75), S-2, S-3 Regional Offices. (Muzaffarabad Maintenance Unit is not included in this survey). The following maintenance units are under a Maintenance Director in the GM Northern Area Regional Office:

① Balakot Maintenance Unit is responsible for the maintenance of N-15,

② Abbottabad Maintenance Unit is responsible for the maintenance of the road section 0–190km of N-35,

③ Dassu Maintenance Unit is responsible for maintenance of the road section 190–350 km of N-

35.

One or two Assistant Directors are assigned under one Deputy Director at each maintenance unit. One or two Site Inspectors are assigned under each Assistant Director. The Deputy Director is responsible for all the sections in their jurisdiction, and one or two Assistant Directors divide these sections and manage them. Furthermore, the Site Inspectors divide the sections under the responsibility of the Assistant Director and manage them respectively.

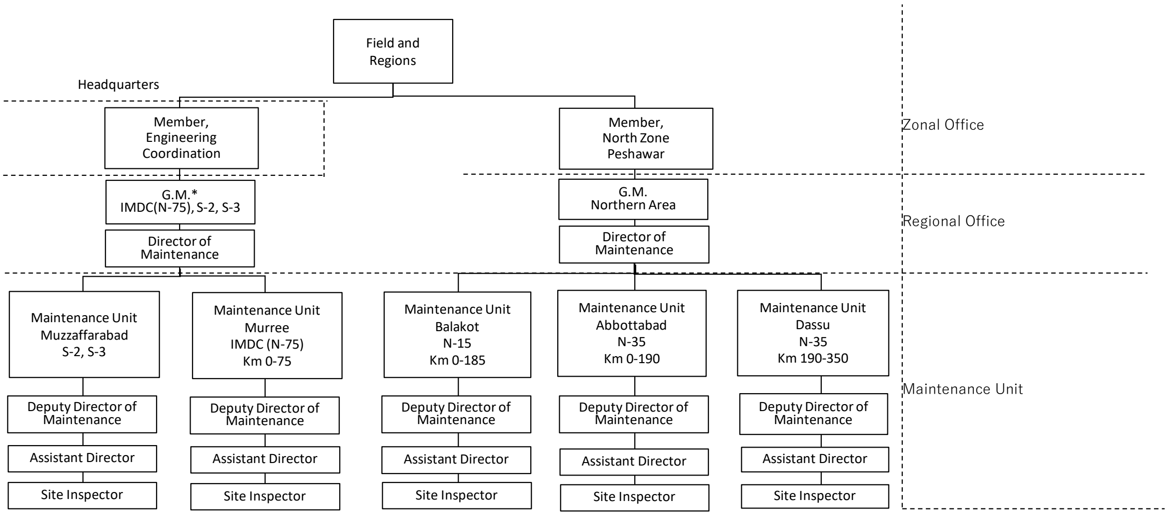


Figure 2.6 Northern Zone Offices, Regional Offices and Maintenance Units
Source: JICA Survey Team

The main activities of the maintenance units are shown below:

- Routine/periodic maintenance: Supervision of cleaning of road facilities, structure inspection, repair, etc.,
- Emergency response: Supervision of removal and clearing of mud flow on roads, slope disaster recovery work, and disaster countermeasure work,
- Special maintenance: Supervision of inspection of pedestrian bridges, maintenance of road facilities, and large-scale repair work.

Regarding the procurement process for routine/periodic maintenance at maintenance units, each maintenance road section is sectioned into 20-km lengths and maintenance contractors are procured through competitive bidding annually, as approved by the Member of the concerned zonal office.

As an emergency response in the event of an unexpected disaster, the maintenance unit orders routine/periodic annual maintenance contractors to remove and clear mud flow on roads. Regarding the procurement process of the disaster countermeasure contractors after road recovery, the maintenance unit engineers arrange the bidding documents based on the standard design drawing. However, in cases requiring special/unprecedented designs, the maintenance unit engineers request the headquarters to assist and provide necessary advice for the design.

c. Salary and Grade of NHA Officers

The total number of NHA staff was 3,252 in 2016, and all engineers are permanent employees. PSDP covers 75–80% of staff salary and allowance, and the remainder is covered by the road maintenance fund, which is funded by NHA toll fees.

The staff grades and titles are shown in Table 2.6.

Table 2.6 Grades and Titles of NHA Officers

Grade	Title
BPS-22	Chairman
BPS-21	Member
BPS-20	General Manager
BPS-19	Director
BPS-18	Deputy Director
BPS-17	Assistant Director
BPS-16	Inspector

Source: JICA Survey Team

The number of permanent staff was registered as 1,100 by the NHA Act when the NHA was established in 1991. After the NHA establishment, the number of staff was increased with non-permanent staff employment. The total number of NHA staff was 3,252[7] in 2016, including 90% permanent staff and 10% non-permanent staff. The total NHA personnel expenses is Rs. 2,943 million, which has increased over 5% from the previous year. The total number of engineers related to road maintenance is approximately 220 at the headquarters, regional bureaus, offices, and maintenance units. The numbers of each engineer are shown in parentheses in Figure 2.5

NHA has not recruited new staff since 2011, owing to the number of registered permanent staff in the Act and as it kept recruiting non-permanent staff. Additionally, a trial for court appealing to employ non-permanent staff as permanent began in 2010; however, a conclusion has not been reached. Thus, the central government being in charge of determining the limitation of human resources of civil servants is not considered positively the employment of new NHA staff.

Staff with skills and motivation will be promoted; however NHA staff are aging, and the staff constitution by age is shifting from a stable pyramid with a large number of junior staff members to an unstable bell with a large number of senior staff members and fewer junior staff. The small number of junior-generation staff at the regional office and maintenance unit may lead to an inheritance gap of technical know-how from the senior generation to the junior generation only on the occasion of on-the-job training. Additionally, it may lead to certain issues. For example, aged engineers at headquarters may keep adopting old landslide measures and remain skeptical to accepting unprecedented new technologies. This will be a hindrance for NHA to develop human resources in the future.

[7] NHA Independent Auditors Report 2016

2.3 NHA Budget for Road Construction and Maintenance

The NHA budget is mainly divided into two parts: road construction and maintenance. The road construction budget is allocated by PSDP federal capital, and the road maintenance budget is allocated by the fund of the NHA-managed Road Maintenance Account (RMA).

2.3.1 Budget Plan for Road Construction and Maintenance

The road construction budget plan process is shown in PSDP in Chapter 2.1.2.

Most of the road maintenance budget, including landslide disaster countermeasures, are allocated by the NHA-managed RMA. The road maintenance budget is extremely small compared to the road construction budget allocated by the federal PSDP, which is the national development budget[8].

The road maintenance actual budget generated through the RMA (Maintenance Total line in Table 2.7) has been 33% to 59% (Actual Maintenance per unconstrained required line underlined) lower than the unconstrained maintenance required (Unconstrained maintenance required under HDM-4 line in Table 2.7) shown in Table 2.7. As a factor of the divergence between the road maintenance necessary budgets and the actual budget amount, the following items are concerned;

- The actual toll fee only covers a small section of the total highway length, which is under NHA's responsibility, and thus it is not sufficient.
- The toll fee is low.

With above factors, the NHA is making efforts and is considering expanding the road section and highway length subject to paying the toll fee and to increase the toll fee, so that road maintenance will be carried out properly.

Table 2.7 Road Related Revenue of Pakistan by Fiscal Year (Unit: Rs. Billion)

		FY2009	FY2010	FY2011	FY2012	FY2013	FY2014	FY2015
Construction (PSDP)		32.3	44.7	28.3	56.5	50.7	57.6	111.5
	Annual growth (%)	12.8	38.4	36.6	99.6	10.3	13.6	93.5
Maintenance								
	Toll revenue	6.5	8.3	10.4	12.4	12.8	14.0	16.0
	Federal grants	0.9	1.0	1.1	1.2	1.4	1.5	1.6
	Others	1.4	2.0	1.6	25.0	2.3	2.9	4.6
	Total	**8.8**	**11.3**	**13.1**	**16.1**	**16.5**	**18.4**	**22.2**
	Annual growth (%)	-	28.3	15.9	22.9	2.5	11.5	20.6
	Unconstrained maintenance required under HDM-4	15.8	19.0	25.1	28.6	28.0	40.4	67.9
	Actual Maintenance required under HDM-4 (%)	55.6	59.4	52.2	56.3	58.9	45.5	32.7

Source: ADB Sector Assessment (Summary) Transport

8 Federal grants in Maintenance column in Table 2.7 is funded by PSDP

2.3.2 Record of Road Construction and Maintenance

The allocation budget for NHA road construction to be distributed from PSDP is Rs. 319.7 billion[9] in FY2017, which is mainly budgeted by the Road Construction Department. The road maintenance budget for FY2016 is Rs. 38.6 billion[10], which is only being spent on road maintenance by the Maintenance Department.

Table 2.8 shows the NHA road maintenance account for FY2012–FY2016. Landslide disaster countermeasures expenditure is covered by the expense items “Emergency Maintenance” and “Hill Slope Stability and Road Protection Works.” Landslide disaster countermeasures expenditure is prioritized to be covered by the “Hill Slope Stability and Road Maintenance Works” account. Once that account is depleted, it is covered by the “Emergency Maintenance” account.

Table 2.8 Breakdown of NHA Road Maintenance Account of 2012–2016 (Unit: Rs. Million)

		FY2012	FY2013	FY2014	FY2015	FY2016
Routine Maintenance		846	1,876	1,245	3,998	4,730
Periodic Maintenance (Functional Overlay)		2,110	2,859	3,811	4,824	4,747
Periodic Maintenance (Structural Overlay)		5,243	5,213	10,117	5,638	5,931
Rehabilitation		2,315	2,899	3,359	2,492	1,335
Highway Safety		500	550	1,000	1,274	951
Others						
	Corridor Management	200	150	50	30	150
	Toll Plaza & Weight Station	450	200	200	600	600
	Administration	775	1,300	1,475	1,418	1,600
	Logistic/ Survey Equipment	60	150	100	70	70
	Afforestation along Highways	80	50	30	30	85
	Emergency Maintenance	**3,600**	**2,071**	**1,300**	**1,600**	**2,275**
	Hill Slope Stability and Road Protection Works	**50**	**50**	**50**	**30**	**200**
	Consultancy Design and Supervision	200	100	80	100	100
	Geometrics Improvement	400	50	100	50	300
	Bridge/ Culvert Structural Maintenance	512	400	322	500	600
	Others	90	10	120	115	85
Grand Total		17,431	17,928	23,359	22,769	23,759

Source: Annual Maintenance Program Report of NHA

2.3.3 Record of Road Maintenance N-15, N-35 and N-75 in 2015

The record of road maintenance for FY2015 along N-15, 35, 75, which are non restricted roads for the JST, is shown in Table 2.9. An emergency project, Keyal Bridge debris removal work, was carried out for restoration at N-35 owing to a disaster that occurred in 2014. In addition, the NHA contracted FWO to implement countermeasures, such as afforestation and retaining wall construction, along N-35 against flooding every year.

[9] PSDP 2017–2018
[10] Annual Maintenance Plan FY2016–2017

Table 2.9 Record of Road Maintenance at N-15, N-35 and N-75 in 2015 (Unit: Rs. Million)

	N-15	N-35	N-75
Routine Maintenance	9.7	21.7	3.9
Periodic Maintenance	59.5	399.2	215.7
Rehabilitation	58.2	2.2	11.7
Emergency		13.7	
FWO*		150.9	
Total	127.4	587.7	231.3

* : Rain/ Flood damage, Construction of Retaining Wall, Causeway, etc.

Source: Road Maintenance Plan of NHA (2016)

The NHA implemented FY2015 restoration projects along the three roads where landslide disasters occurred, which included sediment removal, breast wall, and retaining wall construction. The NHA procured 32 contractors for N-15, three contractors for N-35, and one contractor for N-75, and each contractor has several restoration project contracts with the NHA.

2.3.4 NHA Road Maintenance Account from Fiscal Year 2016–2017

The NHA RMA was established in 2003; the revenue for FY2016 is shown in Table 2.10. The objective budget is obtained by the NHA highway toll fees, police fines, weigh fines, land lease fee from shops on the route site, and federal grants by the PSDP. The budget is for road maintenance expenditure[11]. The NHA road maintenance income shown below.

Table 2.10 Road Maintenance Revenue for FY2016 (Unit: Rs. Million)

Total Revenue		21,402
	Toll Income	17,930
	Police Fine Income	1,890
	Weigh Fine Income	306
	Rental Income	992
	Others	284
Grant		2,375
	Maintenance	2,066
	KKH	238
	S-1	71
Total		23,777
Takeover from previous years		14,798
Total Resources		38,575

Source: Annual Maintenance Plan of NHA (FY2016–2017)

2.3.5 Comparison of Emergency Budget of the Total Budget for Roads with Other Countries

Human resources, budget, and technology are the important elements to implement emergency response. Thus, the percentage for emergency response cost in the general road budget in other developing countries, such as Sri Lanka and Timor-Leste, were compared as shown in Table 2.11[12].

Table 2.12 shows the relation of the emergency budget/total road budget and GDP/capita of the countries mentioned above.

Regarding the budget related to roads in Pakistan and Sri Lanka, both of their road construction budgets are allocated by their government capital, and the road maintenance budgets are allocated by their road managing authority account. Moreover, the Timor-Leste road construction budget and

[11] Maintenance in Grant column in Table 2.10 is funded from PSDP
[12] The data on emergency response cost in the general road budget are only available from the web pages of these countries.

maintenance budget both are allocated by their government capital.

The percentage of the emergency budget in the total road budget is approximately 0.2% in Sri Lanka and Timor-Leste, where the GDP/capita is less than $3,000. The percentage of Pakistan, of which the GDP/capita is less than $5,000, is 3% and thus it can be said that their awareness of the importance of investment in the emergency response budget is higher than the other two countries. It is assumed that the investment in the emergency response budget may increase with economic growth.

The survey team exchanged views with the Member of Planning, NHA regarding the percentage of the emergency response budget allocation in Pakistan in comparison with the other countries. The Member recognized that Pakistan has been achieved its results by their efforts to increase the budget allocation for emergency response. Additionally, they stressed the importance to stop only adopting old design and construction methods and accept the introduction of unprecedented design and construction methods from Japan.

Table 2.11 Percentage of Road Landslide Countermeasures in the Total Road Budget of Each Country

Pakistan — Unit: Rs. Billion

		2012	2013	2014	2015
Government Budget					
	Construction	56.5	50.7	57.6	111.5
	Maintenance (1)	1.2	1.4	1.5	1.6
	Subtotal (2)	57.7	52.1	59.1	113.1
RMA (Road Maintenance Account)					
Maintenance	Routine	0.8	1.9	1.2	4.0
	Periodic	7.3	8.0	13.9	10.4
	Rehabilitation	2.3	2.9	3.4	2.5
	Emergency (3)	**3.6**	**2.0**	**1.3**	**1.6**
	Others	3.4	3.1	3.6	4.3
	Subtotal (4)	17.4	17.9	23.4	22.8
	Gov/Maint.+RMA (1)+(4)	18.6	19.3	24.9	24.4
	Emergency/Total road budget (3)/ {(2)+(4)}	**4.8%**	**2.9%**	**1.6%**	**1.2%**

Source: Road Budget 2009–2015 Federal Government of Pakistan, NHA Road Maintenance Account FY2012–2016

Sri Lanka — Unit: Rs. Billion

		2009	2010	2011	Source
Construction	Expressway	72.9	71.0	86.0	Ministry of Finance
	Improvement	5.5	8.9	14.8	
	Upgrade	15.3	16.0	8.0	
	Subtotal (1)	93.7	95.9	108.8	
Maintenance	Routine	1.3	1.3	1.5	Road Dev. Agency
	Periodic	1.1	1.6	1.5	
	Emergency (2)	**0.2**	**0.2**	**0.4**	
	Others	0.4	1.1	1.6	
	Subtotal (3)	3.0	4.2	5.0	
Others (4)		6.6	7.7	7.5	MOF
Total (1)+(3)+(4)		103.3	107.8	121.3	
	Emergency/Total road budget (2)/ {(1)+(3)+(4)}	**0.2%**	**0.2%**	**0.4%**	

Source: JICA Collection Survey on Road Landslide Measures in Sri Lanka, 2012

Timor-Leste — Unit: USD million

	2015
Emergency (1)	**2.2**
Total Road Infrastructure (2)	783.7

Emergency/Total	**0.3%**

Source: Timor-Leste Road Department, Timor-Leste Ministry of Finance Statistics

Table 2.12 Emergency Budget/Total Road Budget and GDP/Capita of Each Country

	Emergency budget/Total road budget %	GDP/Capita （Unit: USD）	Year
Pakistan	3.0	5,490	2018
Sri Lanka	0.2	2,836	2011
Timor-Leste	0.2	1,767	2015

Source: JICA Survey Team

2.4 Procurement Process for the Road Maintenance Works

This section focuses on the procurement process, from countermeasure engineering design to construction, of emergency response after landslide disaster occurrence.

The NHA does not carry out road maintenance work, but outsources all works for daily/periodic maintenance to local maintenance companies.

Shortly after a disaster occurrence, the maintenance unit orders "road clearance" as an emergency response from the contracted routine maintenance contractor. After the road clearance, the maintenance unit designs, estimates cost, procures, and supervises the countermeasures against further disaster occurrence. The process from engineering design to procurement is shown in Figure 2.7.

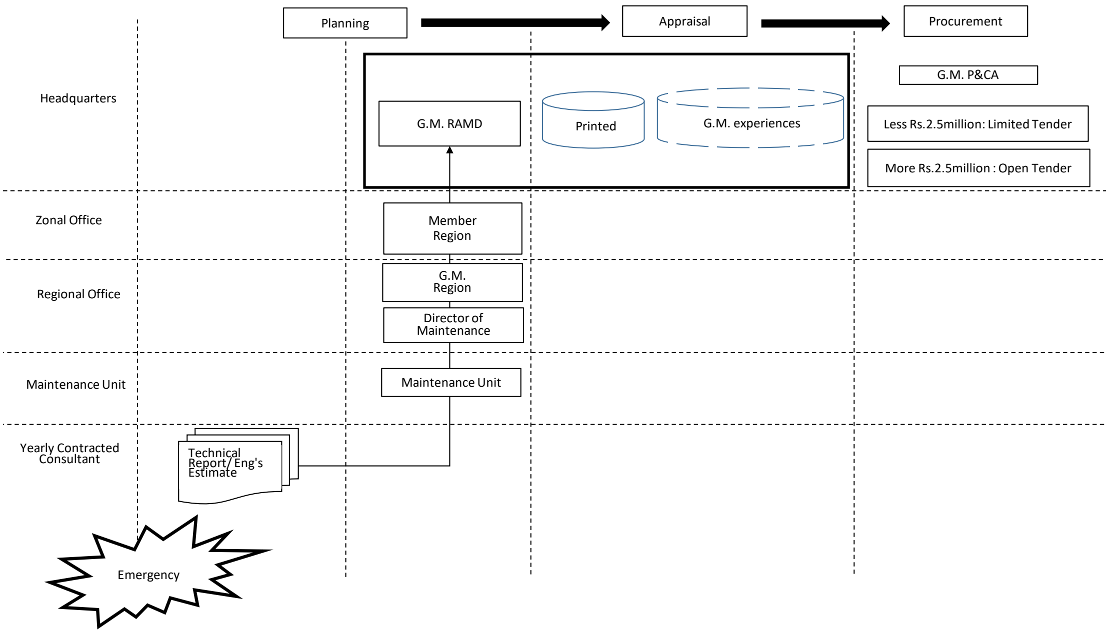


Figure 2.7 Process of Procuring Contractor for Road Landslide Countermeasure Works

Source: JICA Survey Team

RAMD has contracted a consultant company, the president of which is an ex-NHA staff engineer and has a staff of several engineers. As part of this contract, the consultant formulates plans for slope protection countermeasures with close collaboration with the maintenance unit, and supports the maintenance unit in drafting the technical reports/engineer's estimations (hereinafter "technical report") which is submitted to the NHA headquarters through the regional office. Maintenance units or regional offices order to the contracted consultants to formulate and draft a technical report for disaster prevention countermeasures as a part of the contract. Through these processes, the maintenance unit submits the disaster prevention countermeasure technical report to the NHA headquarters. The regional offices are, however, capable to complete small-scale countermeasures, and they implement these independently.

After the NHA headquarters receives the technical reports, GM RAMD and related staff appraise them considering the previous slope protection countermeasures, which the NHA has carried out. However, the technical report appraisal process relies mostly on individual knowledge and experience, and thus the appraisal process should be carried out more efficiently and transparently. The main reason for this is that the files of previous slope protection countermeasures are archived in different places, i.e., the NHA headquarters, regional offices, or maintenance units, and these files are printed documents that are unsystematically filed. Furthermore, GM RAMD has difficulties to propose countermeasures with new technology against the contracted consultant proposals, which propose old design countermeasures[13] such as micropiling (H-shaped steel pile).

The process for procurement of a construction company after the approval of the technical report is divided mainly in two methods: 1) limited contract tender is applied for contracts for less than Rs. 2.5 million; and 2) competitive bidding is applied for contracts for more than Rs. 2.5 million. In the case of the competitive bidding, the evaluation items are: profile/record of the proposed company profile, profiles of engaged engineers, and proposed cost. The evaluation points are 20% for the proposed cost and 80% for the company and engaged engineer profiles. The procurement process period is almost two months, from bidding to completion of the contract.

[13] Refer to 4.5.2 for details

2.5 Large-Scale Road Landslide Countermeasures in N-75

In this section, large-scale landslides that occurred from 2009 to 2015 are summarized. These landslides motivated the NHA to think that countermeasures against landslides were necessary.

After minor landslide disasters repeatedly occurred along N-75, Murree Maintenance Unit implemented several countermeasures, such as protection walls. However, those countermeasures did not function well and led to a large-scale landslide disaster. Figure 2.8 shows the landslide disaster and countermeasures carried out by the NHA in January 2009. Figure 2.9 shows the landslide disaster and a supplemental countermeasure application in 2015 at the same place.

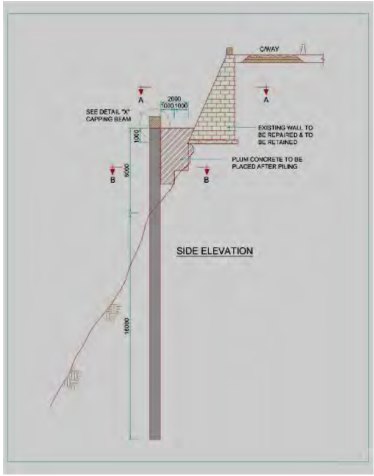


Figure 2.8 Road Landslide (Jan, 2009) and Countermeasure in N-75

Source: JICA Survey Team

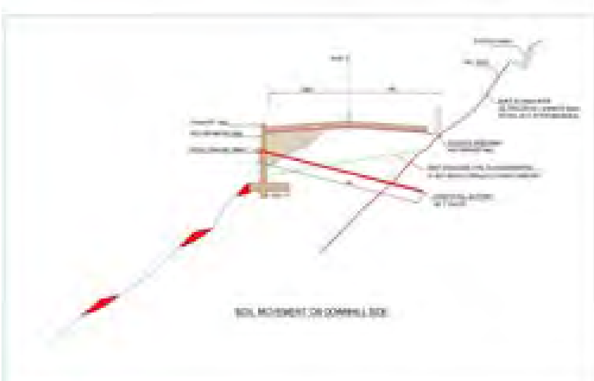


Figure 2.9 Road Landslide (Sep, 2015) and Countermeasure in N-75

Source: JICA Survey Team

These circumstances led the government to establish a Technical Advisory Committee at RAMD, because a series of disasters occurred along N-75 and it has an important function as a strategic road to S-2, S-3. The members of the committee are geological and structural engineers. The Technical Advisory Committee recommended to apply large-scale countermeasures with Rs. 250–300 million at three sections along N-75 in 2014 to 2016 (shown in right side of Figure 2.9). The construction contracts greater than Rs. 100 million are generally covered by the PSDP fund; however, the expense of this large landslide countermeasure was covered from the RMA, which is managed by the NHA, as an exception.

2.6 Database of Road Landslide and Countermeasure Work Records

Databases of road landslide history and countermeasure work history in general are developed to preserve the information or existing data permanently, orderly, and effectively to improve the accessibility and shareability of this type of data. However, the NHA does not possess either type of database and does not keep records of road landslides or countermeasure works specifically. The only documents where there is a trace of past landslides and countermeasure works are the technical reports/engineer's estimations that the field engineers from the NHA regional offices submit to the NHA headquarters. The technical reports/engineer's estimations are explained later in this report[14]. It should be noted that these reports are prepared only to be submitted to the headquarters in order to obtain the required budget from the headquarters. Therefore, small-scale countermeasure works or small-scale landslide deposit removals are not included in these reports. Additionally, these reports are not made with the purpose of recording landslides and countermeasure works, and thus, these are lacking in information, consistency, and reliability, and cannot be considered as a database.

[14] Explained in detail in 4.1.3 Landslide history of the survey target area (road landslide location map)

2.7 Communication & Works (C&W)

2.7.1 C&W in General

The Public Works Department, the former Communication & Works Department (C&W), was established under the provincial government in 1849 to execute all the public works in the Punjab and North-Western Frontier Provinces. In 1955, the Irrigation Division, which belonged to the Public Works Department, was separated to another provincial department. After the separation, construction of public buildings and road construction and maintenance became the main responsibilities of the Public Works Department. In 1979, the Public Works Department was renamed as the C&W Department.

The main tasks of C&W are road maintenance and building of public facilities managed by provincial governments. The details of work activities of the road sector, which is the target of this study, are as follows:

- Maintenance and construction of provincial roads, bridges, and tunnels
- Planning design of road networks
- Road development
- Formulation of standards and specifications of roads and bridges

2.7.2 C&W at PJ Government

a. C&W at PJ government for Road Sector

The road sector of C&W in the Punjab (PJ) government conducts its activities, including construction and maintenance of roads, bridges, and public buildings, in accordance with the Annual Development Programme. The Planning and Design Division of C&W in PJ is in charge of road development planning. The Planning and Design Division creates the road development plan based on the Road Sector Medium-Term Development Framework 2017–2020.

Most of the districts of PJ Province have flatlands and only the northern district has landslide-prone areas. The C&W in PJ has three zones: the North Zone, Central Zone, and South Zone. Among these zones, the North Zone is the only one to face landslide issues. The target area for this study, Murree, Kotli Sattian, and KahutaDistrict[15], where most landslides happen, is located in the North Zone as shown in Figure 2.10 and the Rawalpindi Office is in charge of this area,

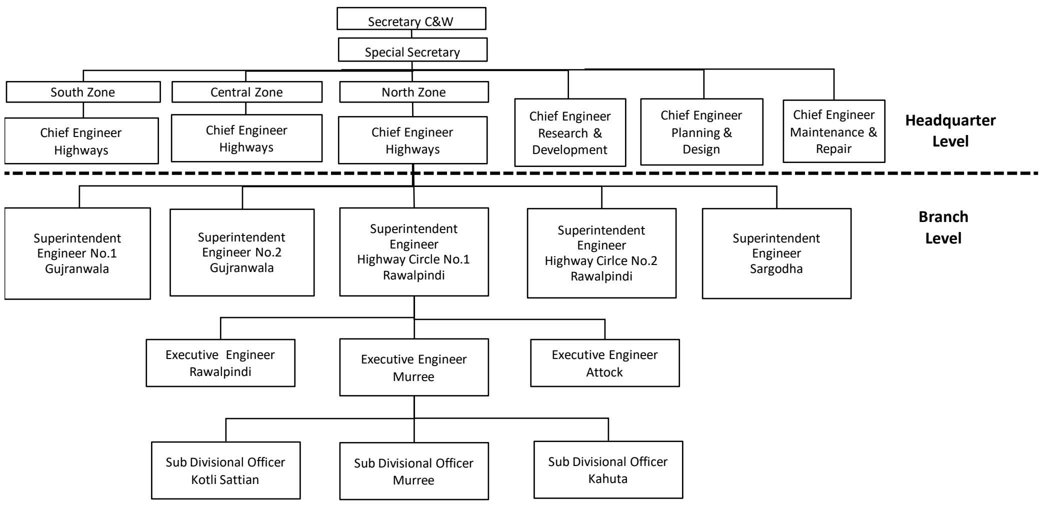


Figure 2.10 Organization Chart of Road Sector of C&W in the PJ Government

Source：C&W updated information

[15] “Murree District” as “Tehsil of District Rawalpindi”

b. Road Sector Medium-Term Development Framework 2017–2020

The government of Punjab has published the Medium-Term Development Framework, 2017–20, with the aim to implement the most cost-effective development and management of provincial roads for the modernization of road networks and road maintenance.

The policy of the framework aims the following:

- Increase the productivity of the industrial field;
- Accelerate the capacity building activities of small and medium enterprises;
- Promote business commerce and trade activities.

c. Punjab Government Budget

The Punjab government budget for 2015–2018 is shown in Table 2.13. The total budget of the Punjab government for 2017–2018 is Rs. 635 billion and the road sector budget is Rs. 90.7 billion, 14% of the total budget of PJ.

The road development and maintenance budget for 2012–2017 is shown in Table 2.14. Table 2.14 shows that the budget of road maintenance is Rs. 100,653 million, 5.6 % of the total budget of PJ in 2017. This maintenance budget includes the costs of road landslide countermeasures.

According to Table 2.15, the labor costs of C&W in PJ is 6.9%[16] of the total budget of the PJ government in 2017. The reason that the cost of labor doubled in 2017 is that the labor costs for C&W in PJ's branch offices were paid by the PJ provincial government; in other words, these costs were not included in the budget of C&W in PJ until 2016. However, the structure of the labor cost payments was changed and therefore, the branch office's labor costs are included in the budget of C&W in PJ from 2017.

Table 2.13 Punjab Government Budget 2015-2018 (Unit: Rs. Million)

Sector		2015-2016	2016-2017	2017-2018
Social Sector		201,636	221,799	243,979
Infrastructure Development		172,164	189,380	208,318
	Roads	**90,700**	**99,770**	**107,747**
	Irrigation	41,031	45,134	49,648
	Energy	9,000	9,900	10,890
	Public Building	15,000	16,500	18,150
	Urban Development	16,433	18,076	19,884
Production Sector		516,974	56,867	62,553
Services Sector		103,350	113,685	125,054
Others		17,803	19,583	21,542
Grand Total		635,000	689,500	768,350

Source: Middle Term Development Framework 2017–20 Vol. II

16 The total amount of the labor cost of C&W in PJ is 6.9%, Rs. 7, 303 million in 2017 (Table 2.12) of the total budget, because the labor costs of C&W in PJ is included in the budget of road maintenance and public building sectors, which is Rs. 105,700 million in 2017 (Roads: Rs. 90,700 million plus Public Building: Rs. 15,000 million (Table 2.10),

Table 2.14 Punjab Government Road Budget 2012–2017(Unit: Rs. Million)[17]

Year	Development	Maintenance	Total
2012–2013	26,193	1,977	28,170
2013–2014	33,837	2,234	36,071
2014–2015	40,837	1,725	42,562
2015–2016	69,400	4,683	74,083
2016–2017	79,000	5,641	84,641
2017–2018	95,000	5,635	100,653

Source: Punjab C&W drafted document

Table 2.15 C&W Punjab Labor Cost 2015-2017 (Unit: Rs. Million)

	2015	2016	2017
Staff Salary	3,612	3,531	7,303

Source: JICA Survey Team

d. C&W PJ Road Sector's Organization Structure

The overview of the organization chart of the Road Sector of C&W in PJ is shown in Figure 2.10. The main C/P for this study of the C&W in PJ is the Superintendent Engineer No. 1 of the Rawalpindi Office. The Rawalpindi Office is divided in two offices, the Rawalpindi No. 1 Office and the Rawalpindi No. 2 Office, referred to Figure 2.11. The Highway Circle of No. 1 Rawalpindi, which has a satellite office in Murree District, manages the landslide-prone area. The Highway Circle of No. 1 Rawalpindi is in charge of the three districts including the Murree Region, but the two other districts do not face landsides issues. At the Murree Region, most landslide occur during the rainy season, July–October. Currently, there are two on-going landslide projects.

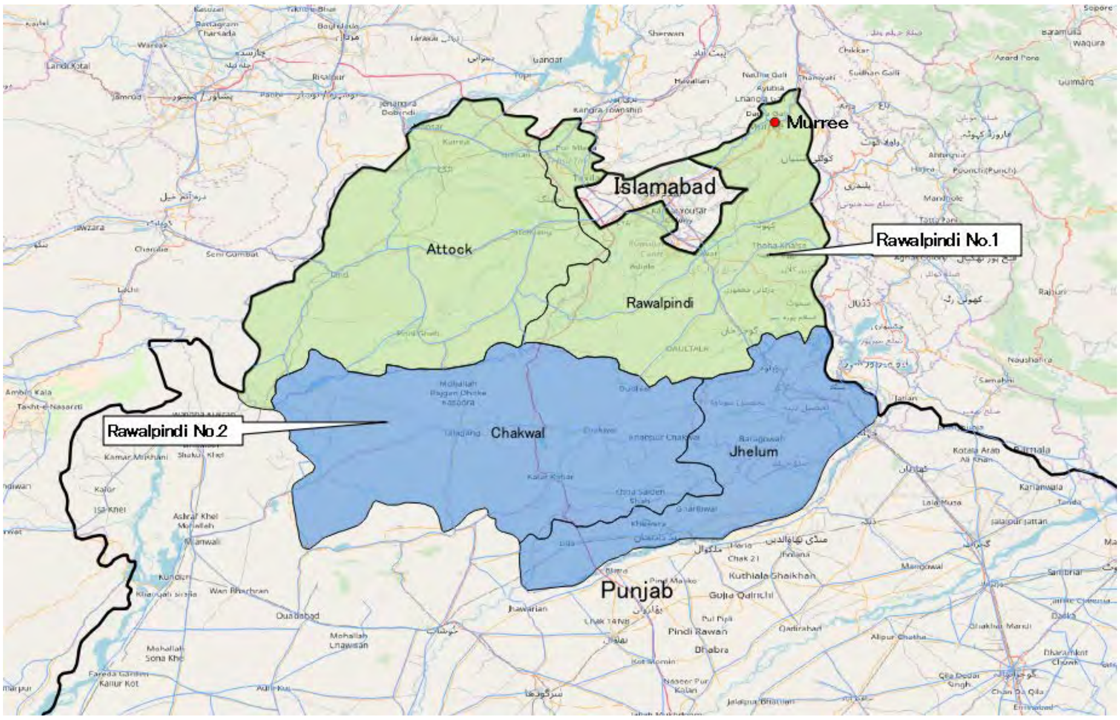


Figure 2.11 District under control of the Highway circle of No. 1 Rawalpindi and the Highway circle of No. 2 Rawalpindi Source：JICA Survey Team

[17]Labor cost excluded

e. Contractor's Procurement Process for Landslide Countermeasure

In the case of landslides occurring along the provincial roads, the sub division officer (SDO) or sub-engineer, beneath the executive engineers, who belong to the branch office, is responsible to conduct a site survey and create a report. This includes pictures of the site survey, preparing design, and cost estimation, and aims to be approved to use the maintenance budget. Then, the executive engineer frames cost estimate against the annual maintenance budget, and submits the report to the superintendent engineer, through the chief engineer, and it is submitted to the secretary from the headquarters for final approval. After the report is confirmed to be valid by the secretary, the branch office starts the tenders for contractors.

After the tender process is completed, the person responsible for approval changes, depending on the bid price. If the bid price is under Rs. 6 million, the superintendent engineer is in charge of the approval. However, if the bid price is over Rs. 6 million, the executive engineer is in charge of the approval.

All works related to landslide countermeasures are subcontracted, and the contractors for design and construction work are decided through tenders. In the last three years, all the design works were carried out by the bidder, National Engineering service in Pakistan (NESPAK)[18]. One of the reasons for this is that their design quality is higher than other consultants in the tenders. Moreover, there are not many tenders for landslide countermeasure works compared to road construction works. Thus, only a few contractors focus on landslide countermeasure works.

With respect to human resources, the Rawalpindi Office is lacking in engineers. Even though the office has requested the recruitment of engineers, it is difficult to recruit new engineers owing to budget constraints. In most cases, the need for new recruitment is on hold until the retirement of engineers who work in the office. The Rawalpindi Office No. 1 has four executive engineers, nine SDOs, and 24 sub-engineers. The SDOs and sub-engineers are responsible for the management of road maintenance, including site inspections, and the supervision of contractors, and thus they are fully occupied by those tasks.

2.7.3 C&W at KP Government

a. KP Integrated Development Plan 2014–18

The Khyber Pakhtunkhwa (KP) provincial government has published its integrated development plan 2014–2018, which gives the priority to the fields of education and health and securing road network. The main goals for the road sector are to ensure a high-quality integrated road network and enhance the local economy through this development.

The main objectives of the road sector are as follows:

- Construction of new road network between cities and road maintenance of existing roads
- Strengthen organization structure for road maintenance
- Utilization of PPP scheme for road sector

b. KP Government Budget

The KP government budget for 2015–2018 is shown in Table 2.16. The road sector budget for the last three years is Rs. 11.5–13.7 billion, which is 9–10 % of the total budget of KP.

[18] Explained by 2.10

Table 2.16 KP Government Budget 2015–2018 (Unit: Rs. Million)

Sector		2015-16	2016-17	2017-18
Social Sector		523	460	460
Infrastructure Development				
	Roads	**13,500**	**11,553**	**13,730**
	Irrigation	6,870	7,050	7,050
	Energy	3,400	3,700	40
	Public Building	1,275	1,439	1,439
	Urban Development	17,766	5,552	6,163
Production Sector		3,471	1,641	1,641
Service Sector		18,480	23,104	26,000
Others		76,715	74,164	69,476
Grand Total		142,000	125,000	125,999

Source: JICA Survey Team

The road construction and maintenance budget of C&W in the KP government for 2012–2017 is shown in Table 2.17.

The cost for landslide countermeasures is covered by the road maintenance budget; therefore, there is no specific budget for landslide countermeasure works. For this reason, C&W in KP decides and conducts the countermeasure works considering their annual budget allocation.

Table 2.17 KP Government Road Budget 2012–2017 (Unit: Rs. Million)[19]

Year	Development		Maintenance		Total	
	Budget	Expenditure	Budget	Expenditure	Budget	Expenditure
2012-13	13,704	12,697	872	769	14,576	13467
2013-14	10,258	16,134	1,881	1,829	12,139	17963
2014-15	9,590	11,840	1,495	1,405	11,085	13245
2015-16	13,500	15,767	2,321	2,216	15,821	17984
2016-17	11,553	21,108	1,969	1,919	13,522	23027
2017-18	13,730	8,879	2,678	-	16,408	8879

Source: JICA Survey Team

According to Table 2.18, the labor cost of KP staff is approximately 16.5%[20] of the total budget of KP. This budget planning is done by the planning department within the headquarters of C&W.

Table 2.18 KP Government Labor Cost 2016–2017 (Unit: Rs. Million)

	2016	2017
Staff Salary	1,300	2,500

Source: JICA Survey Team

c. C&W KP Road Sector's Organization Structure

The organization structure of the Road Sector of C&W in KP is similar to C&W in PJ; they have a secretary at headquarter and chief engineer as the head of the branch office. The target area of this study is the North Zone and East Zone, which are in charge of the Abbottabad District and Mansehra District. Additionally, the Project Management Unit is in charge of the JICA project[21]. The

[19] Excluding labor cost
[20] The total amount of the labor cost of C&W in KP is 16.5%, Rs. 2, 500 million in 2017 (Table 2.15), of the total budget, because the labor cost of C&W in PK is included in the budget of road maintenance and public building sectors, which is Rs. 15,169 million in 2017 (Roads: Rs. 13,730 million plus Public Building: Rs. 1,439 million(Table 2.13)).
[21] Khyber Pakhtunkhwa Emergency Rural Road Rehabilitation Project (Yean Loan)

organizational chart of C&W in KP is shown in Figure 2.12 and Figure 2.13.

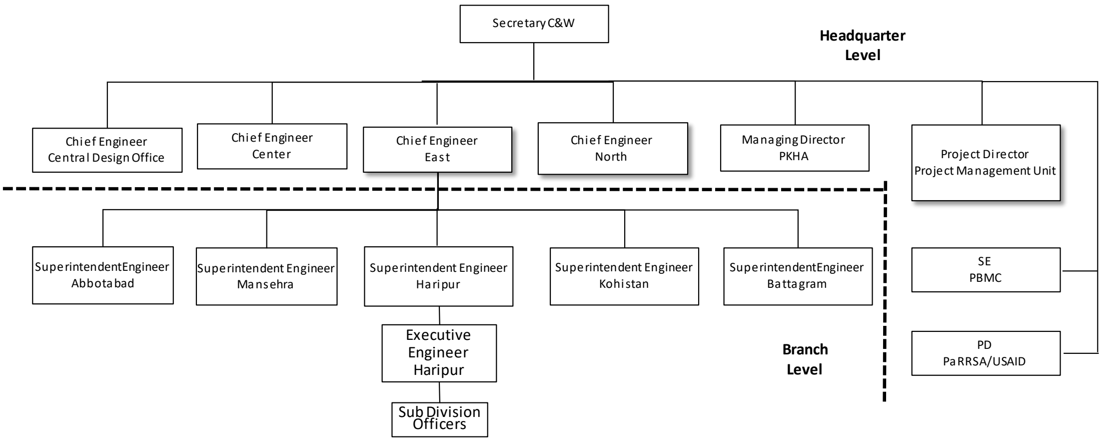


Figure 2.12 C&W in KP Government, East Zone Organizational Chart Source: C&W KP HP

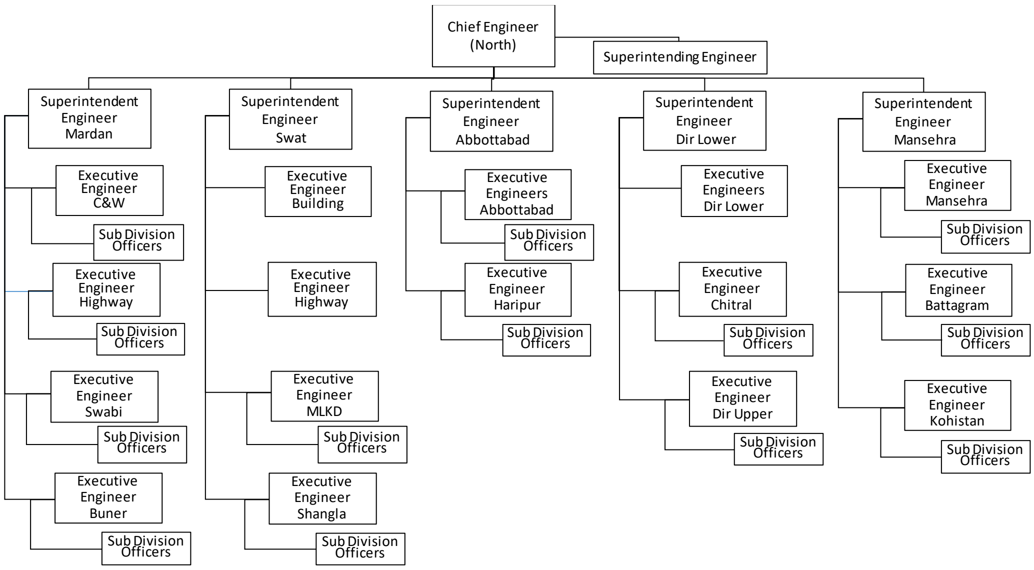


Figure 2.13 C&W in KP Government, North Zone Organizational Chart
Source: C&W KP HP

The SDOs or sub-engineers, beneath the SDO, who belong to the branch office are responsible for road maintenance by conducting visual site surveys. There are no monitoring surveys owing to the lack of monitoring equipment. The most landslide-prone area in PK is the Chitral District, between Chitral - Garam - Chasma Road. Landslide disasters occur after every rainy season in this district; most times they are forced to close the roads. The process for the procurement of contractors for landslide countermeasures are the same as those mentioned above[22].

d. Pakhthunkwa Highway Authority (PKHA)

The C&W in KP is the only C&W that has an inter-district road, apart from the provincial roads. This inter-district road is controlled by the Pakhthunkwa Highway Authority (PKHA) which was established under C&W in KP in 2001. In terms of the organizational structure, PKHA is positioned beneath the secretary, at the same rank as the chief engineers of other C&Ws. However, PKHA operates on a stand-alone basis. Therefore, the road maintenance cost is covered from the collected

[22] Ch 2.7.e

road fees by PKHA, and the deficits are covered from the budget of C&W in KP. Currently, PKHA has 33 inter-district roads, with a length of 2,782 km. The details of the controlled roads are shown in Figure 2.15.

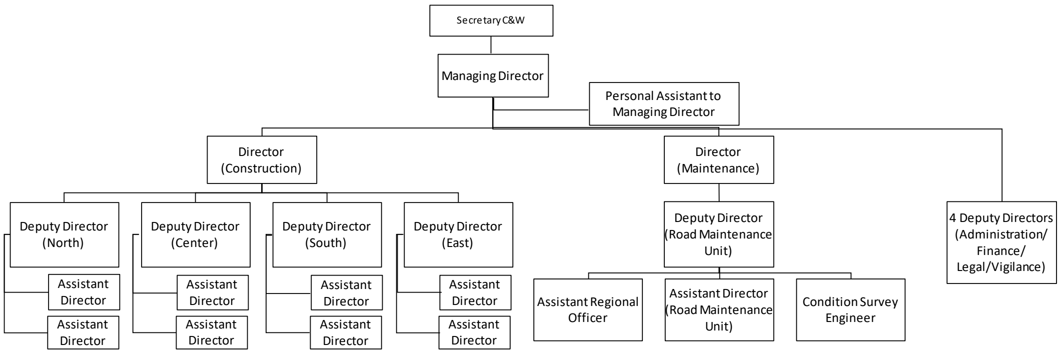


Figure 2.14 PKHA Organizational Chart Source: C&W in KP's HP

Figure 2.15 Map of PKHA controlled inter-district roads Source: C&W in KP's HP

2.7.4 Budget Plan and Road Maintenance for C&W

The road sector of C&W, plans the construction of new roads, daily/regular road maintenance according to the Medium-Term Development Framework and the Integrated Development Plan, and request the budgets for these. For example, the road sector of C&W in PJ road has planned 200 projects in 2017. The projects of C&W are based on the needs of their local communities compared to the NHA, and thus C&Ws tend to have micro-aspects for road plan development.

In terms of road maintenance and daily/regular checks, only visual checks are carried out by SDOs or sub-engineers. Moreover, the reports of repairing design and cost estimate are created based on the knowledge of SDOs and sub-engineers, and thus the quality of the report differs according to the knowledge of the SDOs and sub-engineer at the site survey. For this reason, it is important to improve the knowledge of engineers at the branch level in order to apply new landslide countermeasures. Furthermore, in the case of large-scale landslide countermeasure works, C&Ws order the work from the stage of preparation of the design plan and cost estimation, from NESPAK. However, C&Ws do not have engineers who can examine and judge the adequacy of the design plan and cost estimation submitted by NESPAK. To overcome this issue, JST suggests preparing and conducting the capacity development plan, which is described later in this report.

2.8 Other Donors related to Landslides

2.8.1 Landslide Data by NDMA in Target Area

The National Disaster Management Authority (NDMA) in Pakistan was established under the National Disaster Management Ordinance enacted in 2006 after the earthquake triggered in the northern part of Pakistan in 2005, and the National Disaster Management Act, which was adopted to promote disaster administration focusing on disaster prevention and reduction.

The awareness of landslides and action for measures are stipulated in the National Disaster Response Plan enacted in March 2010, as shown below. (Please note that the term “Landslide” has inclusive meaning internationally that covers the generic phenomenon where a slope consisting of materials such as soil or rocks slides/moves along the surface of the slope.) This action can be judged as plausible/appropriate for the purpose of taking urgent action against slope disasters. (In this case, landslide disasters and sediment disasters are treated as the same and the information source is marked as 【】.) However, the counterpart, NDMA, did not mention the master plan or action plan for road slope disaster prevention.

【National Disaster Response Plan (NDMA 2012)[23]】

The National Disaster Response Plan remarks the following.

The slope disaster is a major disaster, included in the main types of major disasters such as earthquakes, avalanches, glacier lake outburst flood (GLOF), flash flood, and flood. Landslides are defined as phenomena whereby loose soil materials slide/fall owing to heavy rain. Landslides are often seen in the Murree region and other region of Pakistan. These landslides lead to the isolation of villages owing disruption of roads, which results in the loss of lives.

The areas such as Kaghan, Naran, and Chitral in the KP Province, are recognized as landslide prone areas in the National disaster Response Plan.

In the case in which landslide disasters occur, urgent measures will be taken as follows. The District Disaster Management Authority (DDMA), which manages disasters at the local level, will take the first action after the disaster is declared in the District Nazim. A higher-level organization, such as the Provincial Disaster Management Authority (PDMA) and NDMA, and Non-Governmental Organizations (NGOs) will support the actions of DDMA.

2.8.2 Frontier Works Organization (FWO)[24]

According to its HP, FWO is affiliated with the Pakistan Army and is in charge of the arrangement of the social infrastructures such as roads, bridges, dams, and electric utilities/facilities, especially the in frontier region bordering with Afghanistan, China, and India. FWO reconstructed the roads in the landmine area during the Gulf War of 1991 (approximately 3,000 km in Kuwait) and arranged the KKH road (N-35) in Pakistan in collaboration with Chinese companies.

Our survey team applied to interview in relation with the technical records referred to in the report “Structural and Climate of Mass Movement Along the Karakoram Highway (KKH) (Sajid. Ali et.,

[23] National Disaster Response Plan 2012, http://www.ndma.gov.pk/plans/NDRP-2010.pdf
[24] Frontier Works Organization HP: http://fwo.com.pk

al.)"[25] with respect to the damage pattern of road structures and its maintenance.

2.8.3 National Engineering Service in Pakistan (NESPAK)26

NESPAK is major construction consulting company, which is in charge of planning, survey, design, and supervision in the construction of principle social infrastructures. NESPAK is headquartered in Lahore and was established in 1973. NESPAK has a workforce of 5,314 and is a leading company in Pakistan.

The engineer from NESPAK participated in the meeting with C&W in Lahore (1st Nov. 2017) and explained the current situation of how the construction works (Survey, Design, and Implementation of the slope stability works) will be proceeded along the mountain road in the Punjab province. The GEOTECH & GEOENVIRONMENTAL DIVISION, which is concerned with road landslides, is stationed in Lahore and handles the construction management service (Survey, Design, and Construction Management) in road landslides along N-75 in Murree.

[25] Ali, S., Schneiderwind, S., & Reicherter, K. (2017): Structural and Climatic Control of Mass Movements Along the Karakoram Highway, Advancing Culture of Living with Landslides (pp. 509–516), Springer.
[26] NESPAK HP: http:///www.nespak.com.pk

3 Information from Donors

3.1 Japan International Cooperation Agency (JICA)

3.1.1 Khyber Pakhtunkhwa Emergency Rural Road Rehabilitation Project (Development Assistance Loans)

Table 3.1 Outline of Khyber Pakhtunkhwa Emergency Rural Road Rehabilitation Project

Loan Agreement signed on	January 21, 2011
Term	On going
Total Amount of Aid	14,700 million Yen
Project Location	Khyber Pakhtunkhwa Province
Recipient Organization	Communication and Works Department, Government of Khyber Pakhtunkhwa

Source: JICA Survey Team

a. Background

The flood of the Indus river basin brought severe damage to the Project Location, KP Province, between late July and August 2010. According to Damage and Needs Assessment (DNA), coordinated by the World Bank (WB) and ADB, the total reconstruction cost is estimated at US$690 million. Within the total cost, the amount of damage in the road sector in KP Province is US$338 million.

b. Objective

In order to improve regional economic disparities in flood-stricken areas, this project's objective is to restore the road disaster area caused by floods.

c. Project Summary

The Project aims to rehabilitate roads and bridges damaged by the large-scale floods that occurred in July-August 2010. Based on DNA, the Project seeks to contribute to the timely rehabilitation of selected Provincial and District roads and bridges to promptly recover the economic and social life of the local population in the Province.

3.1.2 East-West Road Improvement Project (N70) (I) (Development Assistance Loans)

a. Background

The road condition of N-70 is poor. In particular, the road on the hilly terrain suffers from frequent falling of rocks, debris, and occasional landslides. In addition, because of the narrow road width, coupled with short curve radius and steep slope, one car frequently has to wait for an oncoming car to pass in certain places. In such cases, articulated lorries and trailers need to take an alternative route via N-65.

Table 3.2 Outline of East-West Improvement Project

Loan Agreement signed on	May 3, 2008
Term	On going
Total Amount of Aid	15,492 million Yen
Project Location	Punjab Province
Recipient Organization	National Highway Authority (NHA), Ministry of Communications

Source: JICA Survey Team

b. Objective

The project objective is to facilitate mobility of both people and goods between the east and west of the country by improving the road section between Punjab and Baluchistan on National Highway No. 70 (N-70). It thereby contributes to the socioeconomic development of the Islamic Republic of Pakistan.

c. Project Summary

The following project components are civil work with road widening and realignment, and consulting service with detailed design and tender document support supervision.

3.1.3 Indus Highway Construction Project (III) (P) at Sindh Province (Development Assistance Loans)

The Project aims to promote domestic and international trade as well as accelerate economic development in the areas along the Indus Highway through the construction of an additional two-lane carriageway between Sehwan and Ratodero (approximately 200 km in length) in central and northern Sindh.

The Indus Highway (National Highway No. 55), linking Karachi and Peshawar on the western bank of the Indus River, is one of the key transport routes that form a north-south linkage in Pakistan. The Indus Highway reduces the travel distance between Karachi and Peshawar by 500 km, compared with National Highway No. 5 that runs along the eastern bank of the Indus River.

Japan Bank for International Cooperation (JBIC) has extended loans to support the development of the Indus Highway (the total for six loans is 60.1 billion yen), including the construction of the Kohat tunnel. The remaining road sections have been funded by the Government of Pakistan and the Asian Development Bank, and the construction work is underway. This project will enable the completion of the entire route of the Indus Highway. It is expected that the highway will increase traffic between Karachi and Peshawar as well as with adjoining countries such as Afghanistan. Improved access from rural villages in Sindh to large cities such as Karachi is also expected to contribute to social and economic development in the province’s local communities.

3.1.4 Project for Technical Assistance on Implementation of Bridge Management System in NHA/2016.7-2019.4 (Technical Cooperation)

In Pakistan, the NHA is responsible for the operation and management of the national highway network totaling 12,131 km, which is 4.6 % of the overall road network of Pakistan, including approximately 5,500 bridges and 16,000 culverts. To manage road maintenance, it is a key factor to create an effective system and pursue sustainability of the system. The main reason for these challenges was the shortage of experienced bridge inspectors, equipment, and integration with regional offices and local units. Meanwhile, the maintenance of bridges and culverts has been carried out without any plans. Furthermore, damage and degradation of bridges caused by an increase in traffic volume, overloading, poor design/construction, etc. contribute to an increased risk for the deterioration of bridges.

The proposed project will ensure that the NHA achieves the following:

A) Establishment of a well-trained bridge management unit ensuring sustainable implementation of Bridge Management System (BMS) in NHA.
B) Improvement of bridge inspection methods, procedures, and guidelines
C) Strengthening of NHA staff's capacity to provide timely and effective maintenance

D) Development of mechanisms to improve fiscal/financial sustainability of bridge/structure development and maintenance programs.

3.2 Asian Development Bank (ADB)

3.2.1 Pakistan National Transport Policy and Master Plan

a. General policy on road disaster sector

The draft National Transport Policy of Pakistan contains eight policy objectives, one of which is to "preserve and conserve the environment." One sub-objective is to "mitigate the impact of natural disasters by taking prevention and adaptability measures as well as improving climate change resiliency."

b. Current progress on master plan implementation

Upon the approval of the National Transport Policy by the Government, a master planning process will be initiated, and the master plan is to be prepared by August 2018. However, owing to the delay of the governmental approval, the master plan is under implementation.

3.2.2 Country Partnership Strategy, Sector Assessment Summary on Road Transport

a. Expected ADB interventions

The ADB Pakistan country partnership strategy, 2015–2019, highlights the focus on regional connectivity in transport and energy through ADB support for the following three points:

i. Extension of Central Asian Regional Economic Corridors (CAREC) to the ports of Gwadar and Karachi.
ii. Construction of Turkmenistan–Afghanistan–Pakistan–India natural gas pipeline.
iii. Construction of transport and trade facilitation with the emphasis on development of economic corridors to expand economic opportunities for communities in surrounding areas.

A review of the effectiveness of ADB interventions in Pakistan noted that although some progress had made the transport corridors function better, the NHA's revenue remained insufficient and the administration in provinces in particular had insufficient revenue. The NHA is lacking with regard to asset management systems, sustainable means of revenue generation, contract management skills, needs-based allocations of funds, and operational management. To overcome these issues, the ADB will provide support through the utilization of its experience in various countries.

During 2015–2019, ADB's transport strategy in Pakistan aims to support economic and social development by ensuring that the transport infrastructure is unrestricted, safe, environmentally friendly, and affordable, as proposed in its Sustainable Transport Initiative Operational Plan 12. In the road sector, the ADB will focus on the improvement of regional connectivity, transport efficiency, and road safety, with particular focus on upgrading the CAREC corridors. ADB will continue to assist with the construction or rehabilitation of national and provincial highways, strengthening institutions, and building the capacity of transport agencies in areas such as road safety, strategic planning, transport policy development, road asset management, safeguard compliance, and procurement.

The project is under project preparatory technical assistance with KP government, and the project will include the following:

i. Rehabilitation of 350 km of provincial highways in KP.
ii. Commissioning a routine maintenance work for approximately 200 km of provincial highways combined with connecting district roads based on performance-based maintenance contract.

iii. Enhancement of the functionality of RAMS.

3.3 World Bank (WB)

3.3.1 Khyber-Pakhtunkhwa Emergency Roads Recovery Project Under the KP/FATA/ Balochistan Multi Donor Trust Fund with $8 million in 2011 to 2015

This project carries out emergency rebuilding activities at priority roads that have damaged infrastructure from the conflict in the Province of Khyber-Pakhtunkhwa.

Given the deep crisis situation, exacerbated by the 2010 devastating floods, the main focus of the first set of priorities is the restoration/improvement of pedestrian and vehicular access to some of KP's poorest neighborhoods in the Swat Valley.

The following are the main components:

Component 1: Infrastructure rebuilding involving reconstruction/improvement of strategic roads and bridges.

Component 2: Project management providing support for contract administration/construction supervision and safeguards related to consultant services and incremental operating costs.

The expected outcome is improved traffic flow resulting in reduced vehicle operating costs and travel time for beneficiaries using the road. For measurement of the output, the length of roads reconstructed (km) and number of bridges reconstructed/repaired have been identified as the key indicators. The anticipated results will support governmental efforts to help maintain minimal economic activity and improve the social and political stability in the province. The project will be implemented by the Frontier Highways Authority (FHA), an autonomous roads organization of the Provincial Government of KP.

3.3.2 Landslide Stabilization to Safeguard Civil Population and Infrastructure of Muzaffarabad City in October 2017

The fragile ecosystem and geological formations are highly prone to rainfall water and landslides are a common feature in the area. This has been further aggravated by the earthquake of October 2005, during which the mountains were deeply shaken, wide cracks developed, and slopes became further prone to landslides. These landslides are a permanent threat to the agricultural land, habitations, infrastructure, and human lives.

a. Objective

1) Survey the area around the capital city of Muzaffarabad to assess and map the risk of landslides and debris flows, which cause damage to the habitations and infrastructure.
2) Identify causes of landslides and debris flows.
3) Propose mitigation measures, prepare design, assess the quantity and estimate the cost of construction and treatment to make the city safe against disaster.

b. Project Current Situation

The WB processed a consultant procurement in October 2017; however, a qualified consultant has not been procured. Therefore, the project has been canceled.

3.3.3 Khyber Pakhtunkhwa Provincial Roads improvement Project-Performance Based Maintenance (PBM) Pilot Project Component Oct. 2017

The lack of adequate and reliable funding for maintenance in PKHA's recurrent annual budget has not allowed regular implementation of both periodic and routine maintenance, with most of the available funds used for emergency maintenance operations and works. The deferred maintenance has translated into a substantial maintenance backlog, which now requires a major road reconstruction and rehabilitation project.

The maintenance component of a multi-year PBM contract includes:

1) Routine Maintenance (recurrent, cycle 1 year)
2) Periodic Maintenance (recurrent cycle, 7–12 years)
3) Emergency Maintenance (no recurrent cycle, not predictable)

3.4 China Pakistan Economic Corridor (CPEC)

The CPEC highway network in the Northern Province in Pakistan was initiated in 2013, with the target year set as 2030. In KP and North Punjab provinces, the updated CPEC highway network project is shown in Table 3.3, and maps are shown in Figure 3.1 and Figure 3.2.

Table 3.3 CPEC Highways Network Project along N-35 (as November 2017)

Project Title	KKH Thakot - Raikot N35 remaining portion (136 Km)
Estimated Cost	$719.8 million
Project Progress Update	• Feasibility and PC-I completed • LOI forwarded to Chinese side • Procedural formalities to be completed shortly

Source: http://cpec.gov.pk/infrastructure

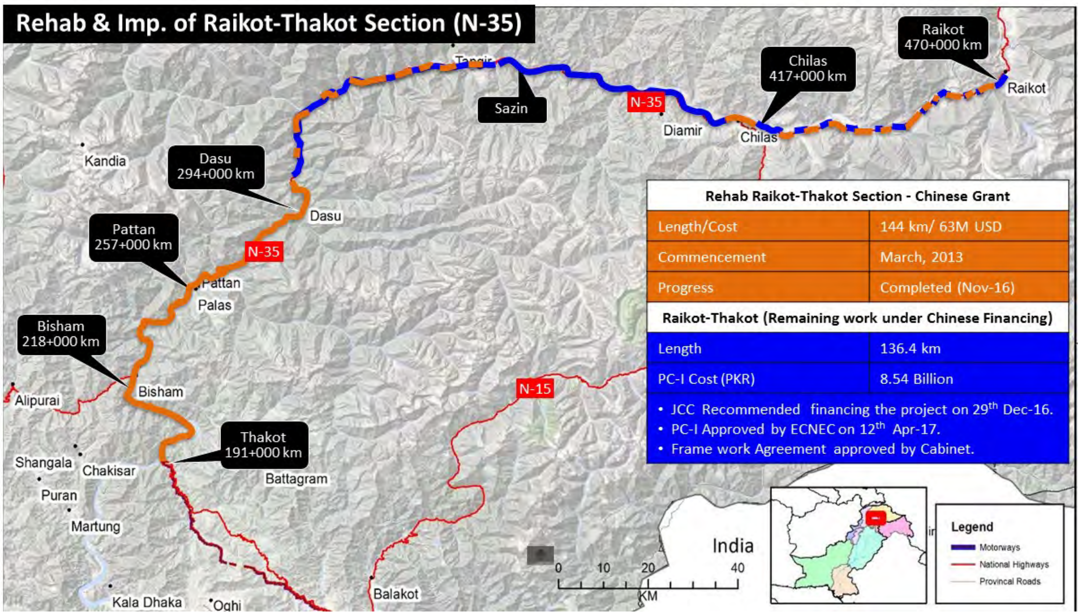


Figure 3.1 KKH Thakot-Raikot N35 remaining portion (136 Km) Source: NHA presentation

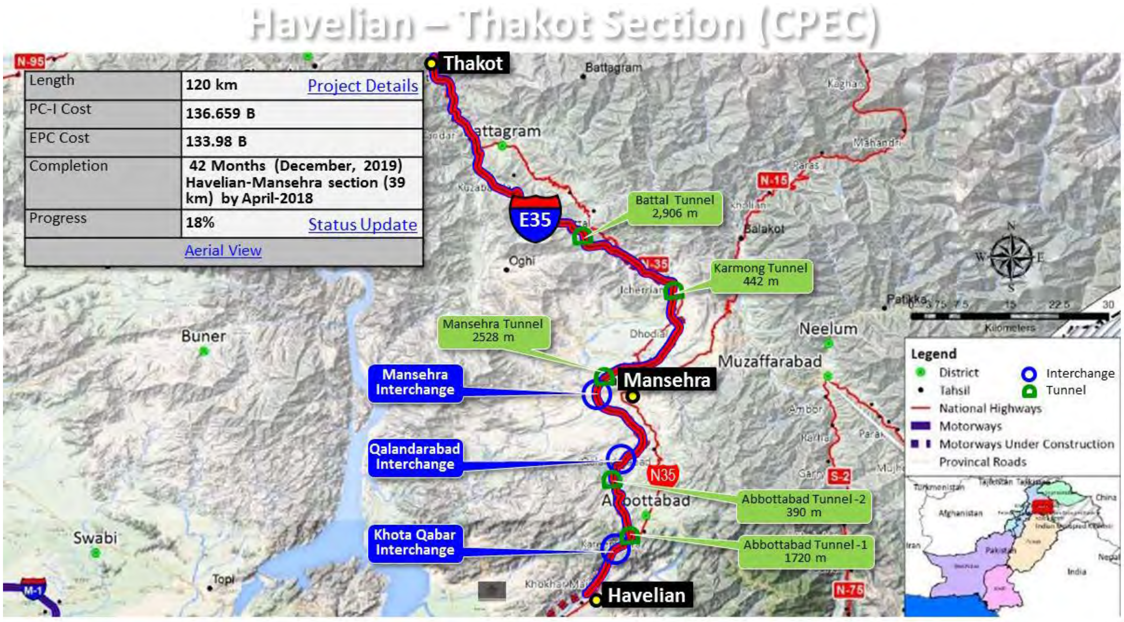


Figure 3.2 KKH Thakot-Havellan N35 remaining portion Source: NHA presentation

Under the policy "One Belt One Road," the Karakoram Highway (KKH) has been regarded important as a transport route of mineral resources such as oil from the Red Sea, especially from Iran. Recently many Chinese companies have shown their presence as much Chinese economic cooperation has been undertaken in Pakistan in the social infrastructure arrangements, such as roads, railways, and power supplies (China Pakistan Economic Corridor HP[27]). The revised Long-Term Plan has been authorized and will be expected to be publicized according to DAWN[28].

With respect to the road sector, especially in N-15/35, the optical fiber installation project is an outstanding project on route of N-15 and five tunnels, named as the China Friendship Tunnel along the Attabad Lake are also outstanding projects on the N-35. The optical fiber installation project will enable the optical fiber network to become the information highway by connecting optical fiber cable from mainland China thorough the Kunjerab Pass, N-35, Chilas, and N-15. The Japanese will enter Naran on the N-15 and many road slopes that could be listed on the long-list exist on N-15. Then, careful consideration should be given to issues such that the optical fiber will not be cut nor broken due to pressure from heavy machines or excavation by heavy machine during the construction countermeasure works on the road slopes. The checking of the installation of optical fiber will be planned in the slope survey, but the uncertainty is high as to whether the point of optical fiber cable embedding can be confirmed or not, because there is no sign (such as marker tape or tracer) nor trace of backfill. The proper management of underground utilities is suggested at the NHA. A database system is needed, such as a shared recording system that shows the locations in which optical fibers are embedded under the road. On-site checking by NHA's staff and installing signs (markers of underground utility) are recommended. The construction of a diverting road was completed in the 24 km section including five tunnels on September in 2015, which had been disrupted due to the Attabad Lake Landslide on route N-35[29]. The safety of the traffic has been secured and the disaster capacity of the N-35 has been improved by this diverting road.

[27] China Pakistan Economic Corridor, http://cpec.gov.pk/
[28] DWAN https://www.dawn.com/news/1372344
[29] Reconstruction of Karakoram Highway, https://en.wikipedia.org/wiki/Reconstruction_of_the_Karakoram_Highway

4 Current situation and Issues of Landslides and Landslide Countermeasures

4.1 Natural and Social Conditions of the Survey Target Area

Pakistan is located in the west of South Asia, and it borders China in the northeast, Afghanistan in the northwest, India in the east, Iran in the west, and the Indian Ocean in the south. Its land area is 796,000 km^2, and its population is approximately 207,800,000[30]. The population density is approximately 260 people/km^2 in Pakistan. The capital city is Islamabad, which is located in the north, and the biggest city is Karachi, which is located in the south and faces the Indian Ocean. The population is mainly concentrated at the plains in the southern foot of the Himalaya/Karakoram mountain range, along the western border with India and along the Indus River.

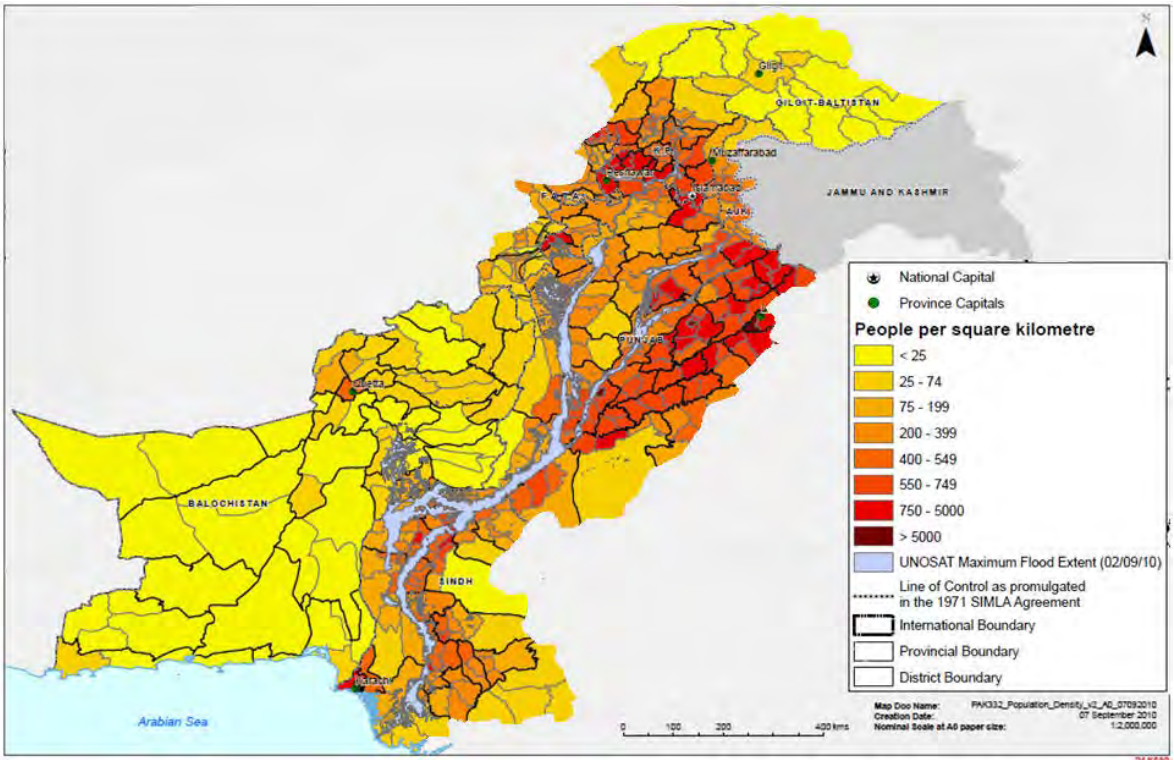


Figure 4.1 Population Density Map of Pakistan
Source: UN Office for Coordination of Humanitarian Affairs

Pakistan's mainland is located in the Asian Continent and it is divided into three major geographic areas: the Northern Highlands, the Indus River plain, and the Balochistan Plateau. The target area of this survey belongs to the Northern Highlands. The Northern Highlands refers to a vast mountainous area that covers the Wester Himalayas (or Kohistan Arc), the Karakoram, the Hindu Kush, and the Pamir Mountains and their surroundings. All the mountain ranges mentioned previously have peaks with more than 7,000 m height and possess large glaciers.

In spite of the active tourism industry in Northern Pakistan, the roads that pass through this area are at a great risk of landslides and other types of disasters owing to severe climatological, geological, and geomorphological conditions.

[30] Census of Pakistan, 2017

4.1.1 Outline of Climatological, Geomorphological, and Geological Conditions of the Survey Target Area

a. Climate of the Survey Target Area

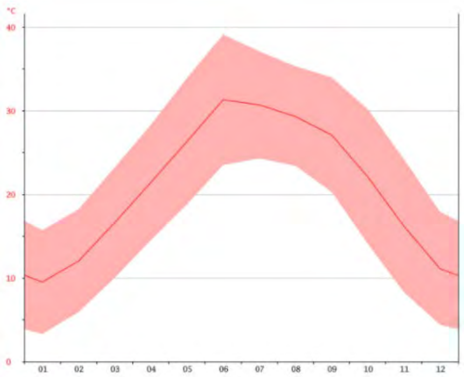
Northern Pakistan is surrounded by the extremely dry Central Asia and South Asia, and is a country under a great influence of monsoons. Therefore, the four seasons can be clearly distinguished and the weather changes intensely depending on the elevation and season. During all seasons, the difference between the daily minimum and maximum temperatures is considerably high. During summer (June to September), the wet atmospheric mass carried from the south due to monsoon discharges in the Lesser Himalayas (Outer Range Mountains), increasing the precipitation remarkably and the precipitations decrease toward the north. During winter (December to February), low pressure atmospheric masses that come from the Mediterranean Sea bring a large amount of snow that charges the glaciers and underground water systems. Spring and autumn are the transitional periods between winter and summer.

As an example of climatological values of non restricted areas for JST in KP, Table 4.1 shows typical climate values for Thakot. This area corresponds to the Humid Subtropical Climate (Cfa) in the Köppen climate classification. The average annual rainfall is approximately 900 mm and the average annual temperature is 21.1 °C.

Table 4.1 Climate in Thakot (KP)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average Daily Temperature (°C)	9.5	12	16.6	21.4	26.3	31.3	30.7	29.3	27.1	22.1	16.2	11.1
Average Low Temperature (°C)	3.3	5.9	10	14.5	18.8	23.5	24.3	23.4	20.3	14.1	8.3	4.4
Average High Temperature (°C)	15.7	18.2	23.2	28.3	33.9	39.1	37.1	35.3	34	30.2	24.2	17.9
Average Precipitation (mm)	68	85	105	81	44	47	154	157	68	26	19	42

Source: CLIMATE-DATA.ORG (https://es.climate-data.org/)



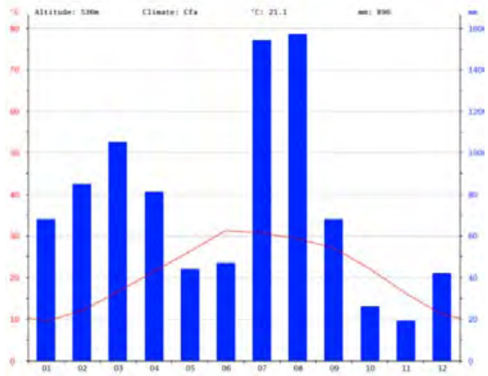


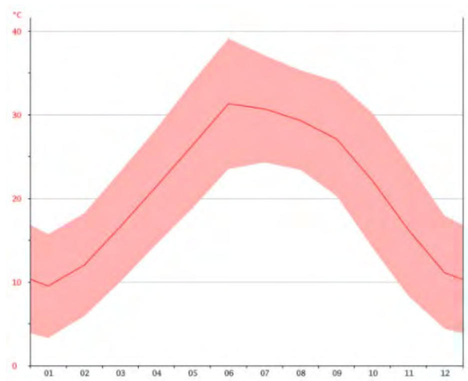
Figure 4.2 Temperature Graph (Left) and Rain Temperature Chart (Right) of Thakot
Source: CLIMATE-DATA.ORG (https://es.climate-data.org/)

As an example of climatological values of accessible areas for JST in PJ, Table 4.2 shows typical climate values for Murree. This area corresponds to the Oceanic Climate (Cwb) in the Köppen climate classification. The average annual rainfall is approximately 1,440 mm and the average annual temperature is 12.7 °C.

Table 4.2 Climate in Murree (Northern PJ)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average Daily Temperature (°C)	3.2	3.7	8.3	13.5	17.4	21	19.4	18.6	17.2	14.4	9.8	5.7
Average Low Temperature (°C)	−0.3	0	4.4	9.1	12.6	16.3	15.7	15.3	13.1	9.7	5.2	1.6
Average High Temperature (°C)	6.7	7.5	12.2	17.9	22.2	25.8	23.2	22	21.4	19.1	14.4	9.8
Average Precipitation (mm)	102	106	131	104	76	99	286	290	124	51	27	44

Source: CLIMATE-DATA.ORG (https://es.climate-data.org/)



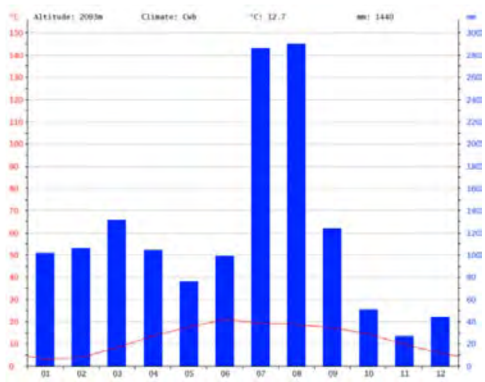


Figure 4.3 Temperature Graph (Left) and Rain Temperature Chart (Right) of Murree
Source: CLIMATE-DATA.ORG (https://es.climate-data.org/)

b. Geomorphology of the Survey Target Area

The Northern Highlands of Pakistan are located and formed in an orogenic belt in the convergent plate boundary between the Indian Plate and the Eurasian Plate. The survey target area is comprehended in the Sub Himalayan, Lesser Himalayan, and High (Great) Himalayan geomorphological areas, that measures more than 300 km from east to west (from the border with India to the border with Afghanistan), and more than 250 km from south to north. The elevation increases gradually toward the north. These areas have large undulations, a difference in altitude of more than 5,000 m and there are multiple peaks that surpass 6,000 m in height. The main ridge line is parallel to the thrust fault and orogenic belt that goes from east-southeast (ESE) to west-northwest (WNW). Perpendicularly to these mountains, there are numerous valleys but the main rivers flow from north-east-north (NEN) to south-west-south (SWS) owing to a sudden surge in the orogenic belt.

Table 4.3 Geomorphology in the area (North to South)

N	High (Great) Himalaya	Its average height is the highest between the geomorphological areas of the Himalayas and has peaks higher than 8,000 m. The Main Central Thrust (MCT) draws a transition line from which mountains rise suddenly on its northern side, forming rock walls and gorges[31].
	Lesser Himalaya	It is located north of the Main Boundary Thrust (MBT) and its width is 100–150 km. The peaks here have altitudes that range from 2,000 to 3,000 m. These mountains are plateaus formed from the remains of old alluvial plains that had risen. It is divided from the High Himalaya by the MCT.
S	Sub Himalaya	The altitude of this expanse ranges between 150 and 1,200 m and its maximum width is 90 km from the south to the north. Its characteristics are hilly areas with gentle slopes and river beds. It is separated from the Lesser Himalaya in the north by the MBT.

Source: JICA Study Team

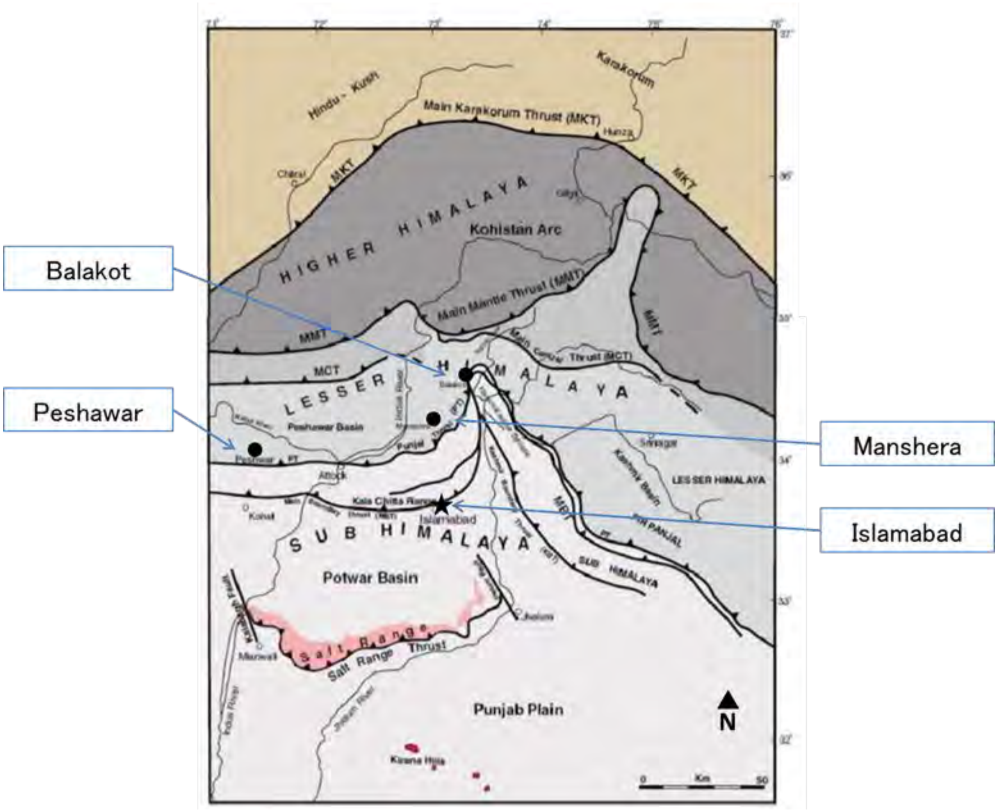


Figure 4.4 Geomorphological areas of Northern Pakistan

Source: Bahria University Islamabad, 2005[32]

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[31] Sakai H. (2000): Natural History of the Himalayas, Tokai University Publisher, Whitehouse, I.E. (1990): Geomorphology of the Himalaya: A Climato-Tectonic Framework, New Zealand Geographer, Vol. 46-2, pp. 75-85

[32] Qadir, A., Ahmad, W. (2015): Geology of Norther Pakistan, A Review, Bahria University

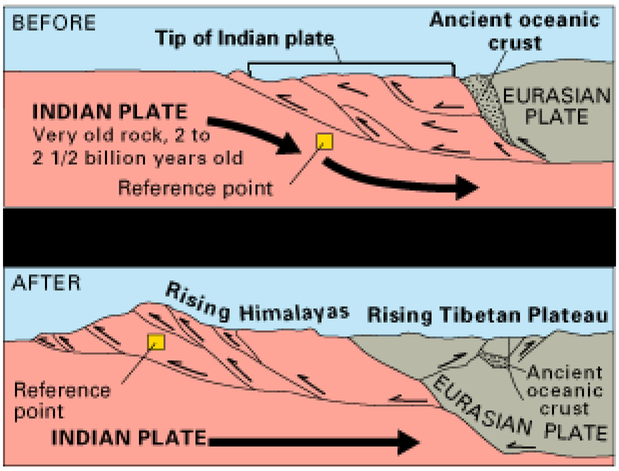


Figure 4.5 Image showing the Indian Plate and the Eurasian plate
Source: http://www.indiana.edu/~g105lab/images/gaia_chapter_13/Fig24left.gif)

Landslides occur frequently in roads where the slopes are very steep and long, especially in the Lesser Himalaya and High Himalaya areas. Moreover, in slopes near thrust fault zones, fold-type structural geomorphology can be seen, where joints and cracks develop more comparing to its surroundings, thereby causing numerous landslides.

In peaks and valleys higher than 4,000 m, the terrain is often covered by hanging glaciers or valley glaciers, which altered the geomorphology. Hence, typical glacial and periglacial landscapes can be identified. Other than the above geomorphological features, collapsed terrain and landslides caused by river erosion are remarkable.

c. Geology of the Survey Target Area of the Survey

Northern Pakistan has sedimentary rocks, igneous rocks, and metamorphic rocks from the Precambrian to the Neogene and has a complex geological structure and history of formation. The geology of the Kohistan Arc can be classified in several ways, but the most representative classification regarding structural geology is as shown in Table 4.4.

Table 4.4 Geology in the area

Siwalik Group (Molasse)	Located in the Sub-Himalayan geomorphological area, the Siwalik Group is composed of layers of crushed sediment deposits (Neogene Molasse) that have been carried to the south by the rivers from the Himalayas. This group shows alternate layers of conglomerate stone, sandstone, and mudstone and the total thickness of these layers can reach to 5,000 m.
Lesser Himalaya	Mainly formed by Precambrian and Paleozoic metamorphic rocks and Paleozoic sedimentary rocks and volcanic rocks that were formed by metamorphic processes. This formation is located between the MBT and MCT faults and has a relatively high stretch width. Rocks in the Lesser Himalaya are fragile because of the remarkable folding mechanisms and movement of the faults.
High Himalaya	This formation comprises metamorphic rocks of the Paleogene (mainly schist, marble, gneiss, amphibolite, and migmatite) and colorless minerals. Igneous intrusions of granites characterize the top of the Lesser Himalaya.
Chilas Complex	It is located in the northern part of the High Himalaya geomorphological area. Its width is 40 km north to south and 300 km east to west, and it is mainly formed by igneous rocks with a high proportion of colored minerals

Source: JICA Study Team

・Tectonics: the survey target area is located in the converging boundary between the Indian Plate and the Eurasian Plate; therefore, it has a high orogenic activity. Owing to this orogenic activity, many faults are moving fast and these faults intersect the roads that pass through the north to south perpendicularly. The main fault systems are the Main Mantle Thrust (MMT) system and Main Karakorum thrust (MKT) with reverse and strike-slip movement. The nearer to these faults, more fragile the nature of the rocks becomes and thus, landslides occur more easily. Additionally, seismic activity is common in the survey target area and plate boundary earthquakes and crustal earthquakes occur periodically. Landslides triggered by these types of earthquakes are also common.

Other than landslides triggered by orogenic activity and earthquakes, slope failures, rock falls, and debris flows are thought to be caused by typical geomorphologies of the Karakoram, such as massive and steep slopes, highly fragile materials, and weathering due to the extremely cold and dry climate[33].

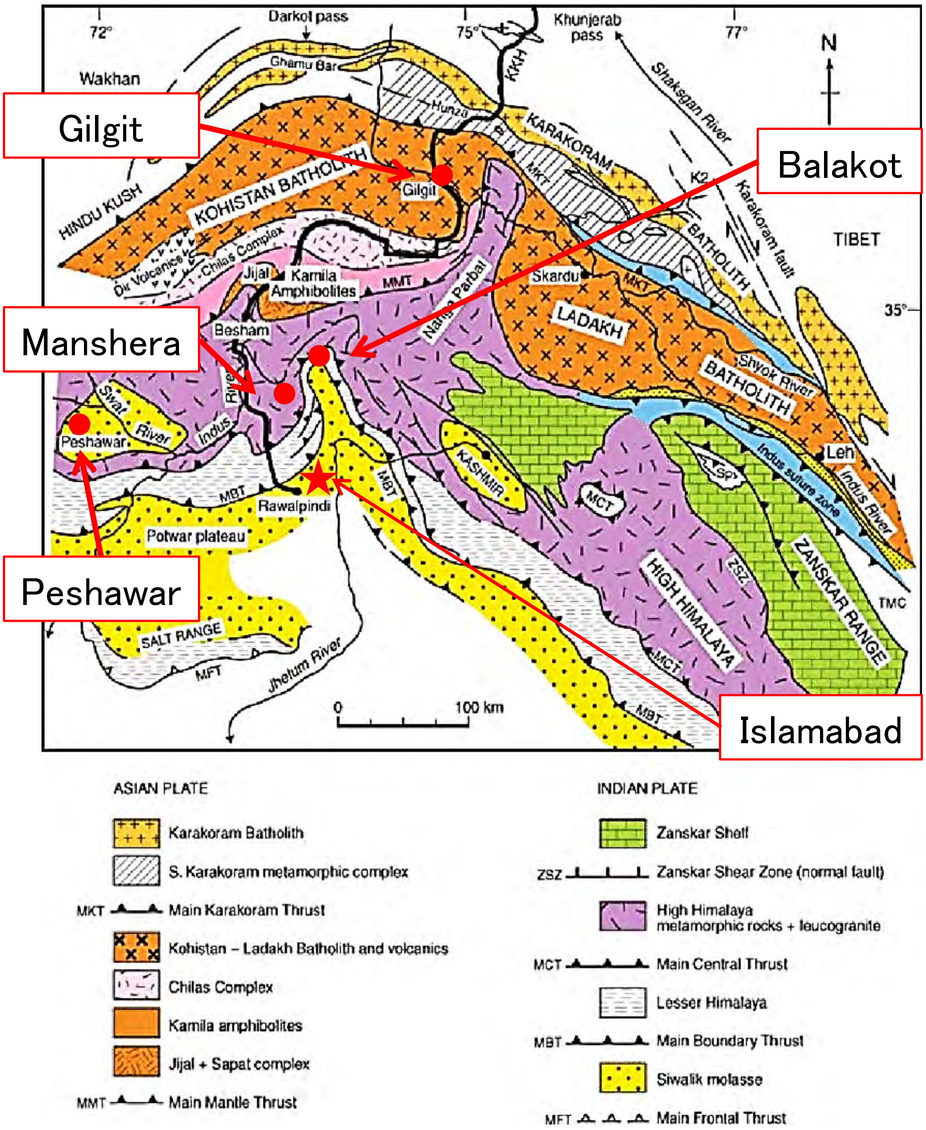


Figure 4.6 Geological map of the Wester Himalaya or Pakistani Himalaya
Source: Searle & Treloar, 2010[34]

[33] Waragai, T. （2008）: Physiographical features in upper Hunza region, Karakoram, Northern Pakistan: Preliminary data, The Institute of Natural Sciences, Nihon University, No.43, pp.67–75.

[34] Searle, M.P., Treloar P.J. (2010): Was Late Cretaceous-Paleocene obduction of ophiolite complexes the primary cause of crustal thickening and regional metamorphism in the Pakistan Himalaya?, Geological Society London Special Publications 338-1, pp. 345–359.

4.1.2 Transport Infrastructure, Industry and Population of the Survey Target Area

a. Transport Infrastructure of the Survey Target Area

Pakistan has transport infrastructure such as railways and airports, but the most common infrastructure for transportation are the roads. Moreover, in the mountainous areas, there are no railways, and the only means of mobilization is the transportation by busses, trucks, cars, and motorcycles. In the recent years, trade and logistics have been improved significantly by the construction of new highways, expressways, and state roads and the widening of old roads. The national highways that cross through the survey target area are N-15, N-35, N-45, N-75, N-90, and N-95. These roads play a critical role of connecting cities in Northern Pakistan. Additionally, Northern Pakistan is a famous tourist destination to visit its mountains and glaciers, and the roads are the only means of access for tourists. It should be noted that N-35 is the only route that connects China and Pakistan, and therefore it is the focus of consideration in Pakistani national policy as part of the CPEC. Thus, road improvement constructions, including road widening, tunnels, landslide countermeasures, etc., are underway.

The recent economic growth of Pakistan has not only developed several national highways and state roads but has also increased traffic density, causing frequent occurrences of landslide disasters, and thus further increasing the risk of landslides Roads are closed for hours due to landslides — especially in summer because of its heavy rains, raining season — which have a significant impact on the economy as these roads do not have alternative routes that can cover the same functions of these roads.

b. Industry

・Northern PJ: Punjab is the state that most contributes to the GDP of Pakistan, with more than 50% of GDP. Its primary sector is mainly grain and cotton production by a canal irrigation system, but it also cultivates rice, sugar cane, corn, and fruit. Regarding animal farming, the poultry industry is the most important. The secondary sector is the most advanced industry in Pakistan and its most important productions are textile, heavy machinery, electric appliances, surgical instruments, and cement. The tertiary sector (service industry) accounts for more than 50% of the GDP of Pakistan and is the most important compared to the other regions.

・KP: The GDP of KPs is equivalent to 10% of the Pakistani GDP and the main industries in the primary sector are agriculture, forestry, and mining. Regarding its secondary sector, the industries for processing the products obtained from the primary sector are the main economic activities. The main agricultural products obtained from KP are grains, corn, sugar cane, tobacco, and fruit. The main underground resources for mining are coal, marble, rock salt, and plaster. The statistics for each economic sector in KP are not clear, but the relative importance of the tertiary sector is thought to be low.

The transportation of the products obtained in the primary and secondary industries are mainly carried out by trucks through roads.

c. Population

・PJ: the population of PJ is 110,012,442[35], more than half of the population of Pakistan. Its population density is 536 people/km^2, which is the highest among all states after the Capital Territory

[35] Census of Pakistan, 2017

of Islamabad. The biggest city is Lahore and approximately 60% of the population lives in cities. The other 40% of the population lives in rural areas. The survey target area, PJ, is one of the places with the lowest poverty rates[36] in Pakistan and is relatively developed in comparison to its surroundings. The poverty rate of PJ is approximately 30% and its sex ratio is 103.5.

・KP: the population of KP is 30,523,371[37], and its growth rate is the highest in Pakistan since 2000, although only 20% of its population lives in urban areas. Moreover, it is thought that approximately 1,500,000 migrants, mainly from Afghanistan and Tajikistan, live in KP and are not registered as residents in Pakistan. The poverty rate of KP is approximately 50 % and its sex ratio is 102.7.

4.1.3 Landslide History of the Survey Target Area (Location Map of Road Landslides)

NHA does not record the occurrence of landslides of its roads; therefore, they do not collect detailed information or possess a disaster history list that has consistency and reliability. The only documents where there is some type of record of landslide disasters are the technical reports that are submitted by the Maintenance Units to the Headquarters.

Technical reports are elaborated by engineers from the maintenance units to request the approval of outsourcing the construction and works (countermeasures against landslides disasters) that need to be covered by the budget of the headquarters. Moreover, staff from the regional bureaus and below propose the contents and estimate the budget of the construction and works and include this on the technical reports. The main contents of the technical reports are as below.

- Basic Information (location, date, etc.)
- Description of the problem that has been identified and explanation of the possible causes (for example, closure of road due to damage of road structures)
- Proposal of solution (for example, reparation of road structures, construction of new road structures, or removal of landslide debris)
- Estimated cost of proposed works
- Photographs of the site

In the case that the required works are simple, the drawings and cost estimation of these are annexed in a report to request the approval of outsourcing these works. In the case that the works are complicated and cannot be designed and its cost cannot be estimated by the engineers in the maintenance units, they request the headquarters to dispatch a specialist who can solve the issue. In this case, the specialist (which is normally an external consultant), carries out the site survey and proposes solutions, designs drawings, and carries out a cost estimation instead of the corresponding engineers of the Maintenance Units. Other than the requests for construction, renovation, and improvement of road structures, the technical reports also include requests for debris removal works owing to landslides on roads. Moreover, these technical reports do not have a fixed form.

The headquarters analyzes these technical reports and considers the following: whether the proposed works or constructions are necessary; if they are urgent; if the measures suggested are adequate; if they are economically feasible; and if there is enough budget to carry out the project. The works or constructions suggested in the technical reports are approved depending on the items above. In order to keep track on the works approved, RAMD records the contents of the approved technical reports. The recorded information includes the involved maintenance unit, road, reference number, type of

[36] The poverty rate is considered as the percentage of people living beneath Pakistan's Poverty Line in the 2013–2014 Household Integrated Economic Survey data. The Poverty line for 2013–2014 is 300 Rs. / day.
[37] Census of Pakistan, 2017

construction/work, distance mark (kilo post), contractor (bidder), date of award, and budget. The reports are not archived properly and are disposed of or randomly stored in a warehouse.

NATIONAL HIGHWAY AUTHORITY

MONTHLY PROGRESS REPORT OF MAINTENANCE CONTRACTS, F.Y. 2012-13

NORTHERN AREAS

S. No	Maintenance Unit	Route	Financial Year	Scope of Work	Location	Name of Contractor	Date of Award	Engineer's Estimate	Bid Cost (Rs.) Original
1	Bkt	N-15	2012-13	Emergency maintenance w ork	26.000	M/s Gul Haider & Sons	2013/4/2	1,952,935	1,952,935
2		N-15	2012-13	Removal of snow / glaciers / slides	80.000			3,256,359	
3		N-15	2012-13	Removal of snow / glaciers / slides	100.000			7,333,333	
4		N-15	2012-13	Removal of snow / glaciers / slides	123.000			2,731,953	
5		N-15	2012-13	Removal of snow / glaciers / slides	140.000			2,818,755	
6	Bkt	N-15	2012-13	Construction of temporary Toll Plaza	40.000	M/s Gul Haider Khan & Sons	2012/11/22	6,368,574	7,705,975
7		N-15	2012-13	Emergency maintenance for keeping diversion operational at Battakundi Nallah	138.600			913,828	
8		N-15	2012-13	Slide clearance	40.000			779,789	
9		N-15	2012-13	Slide clearance	64.000			746,661	
10		N-15	2012-13	To keep diversion operational	138.600			719,095	
11	Bkt	N-15	2012-13	Removal of slides and rocks from road surface	124.000	M/s Dhangla Par Construction	18-9-2013	885,392	885,392
Sub Total (N-15)								**28,506,674**	**10,544,302**

Figure 4.7 Example of Record, Approved Technical Report Source: NHA

The JICA Survey Team has obtained the above record of the survey target area and extracted the works that contained the keyword "slide" (most of the works that contain the keyword "slide" refer to landslide debris removal works) and made the list below. Additionally, the locations of each of these works has been plotted in the following map.

Table 4.5 Works Related to Slides in the Target Survey Area from 2012–2017

Num	Road	Year	Contents	Kilo post	Office
1	N-50	2012-13	Repair / construction of damaged retaining walls	387.00	KP
2	N-50	2012-13	Emergency maintenance work (removal of hill slide material)	387.00	KP
3	N-50	2012-13	Emergency maintenance work (removal of hill slide material)	400.00	KP
4	N-50	2012-13	Emergency maintenance work (removal of hill slide material)	405.00	KP
5	N-50	2012-13	Emergency maintenance work (removal of hill slide material)	412.00	KP
6	N-50	2012-13	Emergency maintenance work (removal of hill slide material)	417.00	KP
7	N-50	2012-13	Emergency maintenance work (removal of hill slide material)	420.00	KP
8	N-50	2012-13	Emergency maintenance work (removal of hill slide material)	430.00	KP
9	N-90	2012-13	Mechanical clearance of snow / slide disposal	10.000	KP
10	N-95	2012-13	Mechanical clearance of snow / slide disposal	95.000	KP
11	N-95	2012-13	Mechanical clearance of snow / slide disposal	106.000	KP
12	N-15	2012-13	Removal of snow / glaciers / slides	80.000	NA
13	N-15	2012-13	Removal of snow / glaciers / slides	100.000	NA
14	N-15	2012-13	Removal of snow / glaciers / slides	123.000	NA
15	N-15	2012-13	Removal of snow / glaciers / slides	140.000	NA
16	S-2	2012-13	Removing of huge landslide and maintenance	3.000	PJ
17	N-15	2013-14	Snow/avalanches/slides clearance	119.000	NA
18	N-15	2013-14	Snow/avalanches/slides clearance	135.000	NA
19	N-15	2013-14	Snow/avalanches/slides clearance	150.000	NA
20	N-15	2013-14	Removal of slide	56.450	NA
21	N-15	2013-14	Removal of slide	68.500	NA
22	N-35	2013-14	Removal of slides	165.000	NA
23	S-2	2013-14	Clearance of slide and construction of breast wall	0.000	NA
24	N-75	2013-14	Removal of landslide	41.500	PJ
25	N-75	2013-14	Construction of Culvert and Landslide Area Remediation	34.900	PJ
26	N-90	2015-16	Removal of Hill Slides	41.680	KP
27	N-90	2015-16	Removal of Hill Slides	15.000	KP
28	N-95	2014-15	Restoration of Road due to Rain/Flood & Removal of Slides	82	KP
29	N-15	2014-15	For removal of snow/glaciers/slides clearance	105.000	NA
30	N-15	2014-15	For removal of snow/glaciers/slides clearance	119.375	NA
31	N-35	2014-15	Construction of diversion over Dassu Slides	298.000	NA
32	N-15	2014-15	Removal of snow / glaciers / slides	119.375	NA
33	N-75	2014-15	Removal of land slide	27.600	PJ
34	N-75	2014-15	pre-cautionary measure for the collapsed SBC due to Landslide	39+000	PJ
35	N-75	2014-15	Removal of Landslide	45+600	PJ
36	N-75	2014-15	Removal of Land Slide	27+600	PJ
37	N-50	2015-16	Clearance of Hill slides, slush & big shoulders	425.000	KP
38	N-50	2015-16	Clearance of Hill slides, slush & big shoulders	410.000	KP
39	N-90	2015-16	Removal of Hill Slides	27.625	KP
40	N-90	2015-16	Removal of Hill Slides	9.400	KP
41	N-90	2015-16	Restoration of damages, Removal of slides & Washedout Road	8.500	KP
42	N-90	2015-16	Restoration of damages, Removal of slides & Washedout Road	25.000	KP
43	N-90	2015-16	Restoration of damages, Removal of slides & Washedout Road	17.015	KP
44	N-95	2015-16	Removal of hill Slides	4.225	KP
45	N-95	2015-16	Removal of Hill Slides	41.680	KP
46	N-95	2015-16	Removal/Clearance of Slide Material/Boulders	77	KP
47	N-75	2015-16	Highway Safety Measures due to active slip circles land slide	29	PJ
48	N-75	2015-16	Failure of slope	26.300	PJ
49	N-15	2015-16	Removal of slides	56.450	NA
50	N-15	2015-16	Removal of Slides	63+900	NA
51	N-15	2015-16	Removal of Slides	97+500	NA
52	N-15	2015-16	Removal of Slides	60+100	NA
53	N-15	2015-16	Removal of Slides	64	NA
54	N-15	2015-16	Removal of slides	142.000	NA
55	N-15	2015-16	Removal of Slides	64.000	NA
56	N-15	2015-16	Removal of Slides	127.000	NA
57	N-15	2015-16	Removal of Slides/Blasting	97+800	NA
58	N-15	2015-16	Removal of Slides	119.000	NA
59	N-15	2015-16	Removal of Slides	127.000	NA
60	N-35	2015-16	Clearance of Slides/Debris	127.000	NA
61	N-35	2015-16	Clearance of Keyal Slides and Repair of damage Keyal Bridge	266.000	NA
62	N-35	2015-16	Diversion Over Dassu Slides and Repair	190.000	NA
63	N-45	2016-17	Removal of Slide Material/Debris	248.00	KP
64	N-45	2016-17	Removal of Slide Material/Debris	310.00	KP
65	N-90	2016-17	Removal of Hill Slides	27.600	KP
66	N-90	2016-17	Removal of Hill Slides	15.000	KP
67	N-90	2016-17	Removal of Hill Slides due to rain	22.300	KP
68	N-90	2016-17	Removal of Hill Slides due to rain/flood	28.700	KP
69	N-95	2016-17	Removal of Hill Slides	109.000	KP
70	N-75	2016-17	Slope stability measures of road section due to landslide	28.230	PJ

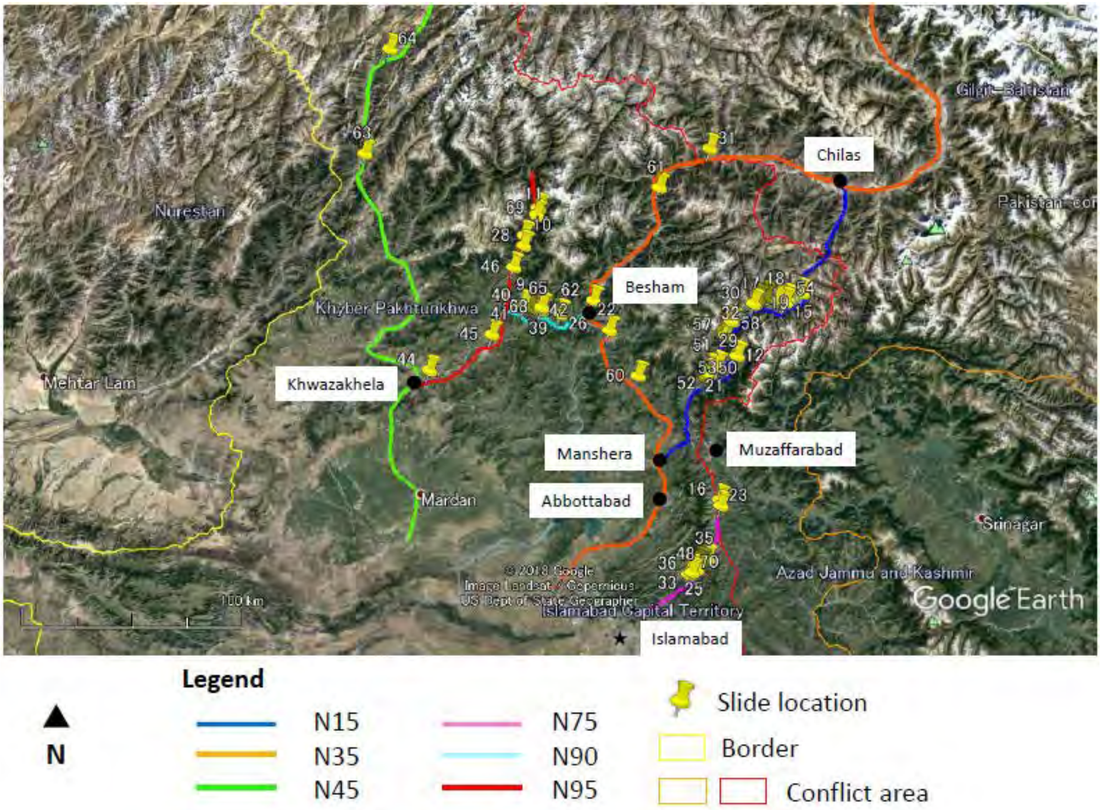


Figure 4.8 Location Map of Road Landslides according to NHAs Record

Source: Google Earth

Basic information of the landslide disasters, such as the type of disaster occurred, its scale, the effects that it had on the road, and the damage it produced, cannot be identified through this list but the trends can be identified by plotting the disasters on a map. The trends identified through the location map are as follows:

- Most of the landslides that have occurred since 2012 according to NHAs record have happened along N-15, from Kholian to Jalkhad.
- In relation to its length, many landslides have occurred in N-90.
- In relation to its length, the landslides that have occurred along N-35 are very few.
- Although it is not in the survey target area, many landslides have occurred along N-50 in Balochistan (refer to the figure below).

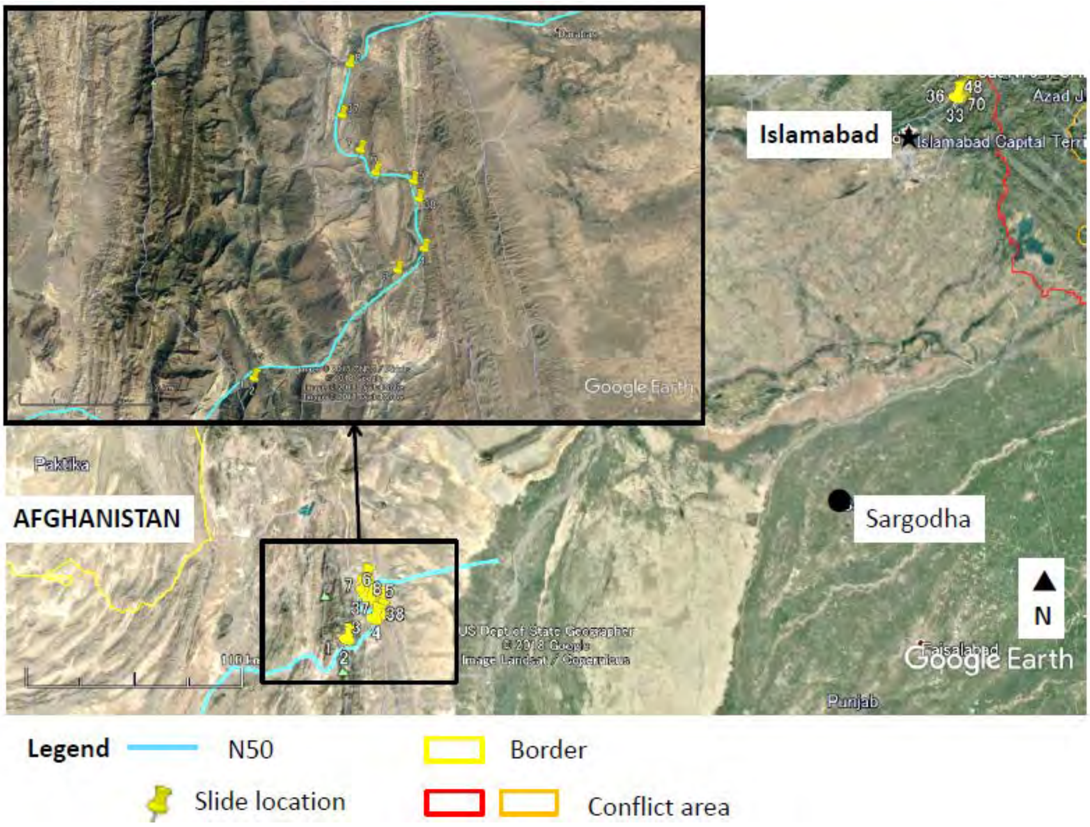


Figure 4.9 Location Map of Road Landslides in N-50 according to NHA's Record

Source: Google Earth

Some words about identified trends of landslide, possible causes and their relation with geology and geomorphology of the area as studied by JST.

4.2 Selection Method to Narrow Down the Lists

The selection of the priority sites for countermeasures was carried out through three stages as shown in the flowchart below (location information is attached in Appendix 2: "Survey Results of Slope Chart").

Creation of Long List:

- The types of disaster (landslide, slope failure / rock fall, debris flow) to be covered in this project were decided.
- The slopes with risk of landslide disasters on roads by each type of disaster were extracted through the interpretation of slopes along the national highways and topographical variations (linear topography, such as slope topographical deformation, and faults) in the target area utilizing satellite imagery of the northern region of Pakistan.
- From the extracted slopes with risk of landslide disaster, the relatively large-scale sites along the main national highways N-15, N-35, and N-75 were selected. Those sites were set as "long list Candidate Slopes" and were selected as targets for the creation of slope chart.
- "Pakistan Simplified Slope Charts" (hereinafter, Simplified Slope Chart or Slope Chart) were created for the slope surveys on site by combining the findings of the Japanese research team and the suggestions of the Pakistan University professors (geologists). The Japanese survey team conducted on-site surveys of the long list candidate slopes in the non restricted area, and the Pakistani professors conducted on-site surveys in the restricted area. Then, the long list was finalized based mainly on opinions of the NHA regional bureau, on-site situation, and other factors observed during the field survey.

Creation of a Middle List:

- From the long list, a "Middle List" was created by selecting the high-priority sites for countermeasure implementation and considering natural conditions (the scale of disaster hazard, such as the width and height of the slopes, the amount of sediment expected due to failures, the distance from roads to slopes, etc.) and socioeconomic conditions (traffic volume, redundancy of routes, such as existence of alternative routes, and importance as emergency road in the case of disasters for local communities, etc.). The middle list was selected from the long list in the non restricted area for the JST.

Creation of a Short List:

- The middle list was narrowed to a "short list" based on the technical viewpoints, such as the scale of slopes and countermeasure works expected on each slope, the technical difficulties, the existence of differentiation factors of countermeasure technologies, and the strategic viewpoints, such as existence of the infrastructure projects of other donors. Approximately five sites from the non restricted area for the JST were selected for the short list, and recognized as target slopes for possible technical assistance of countermeasures in the future.

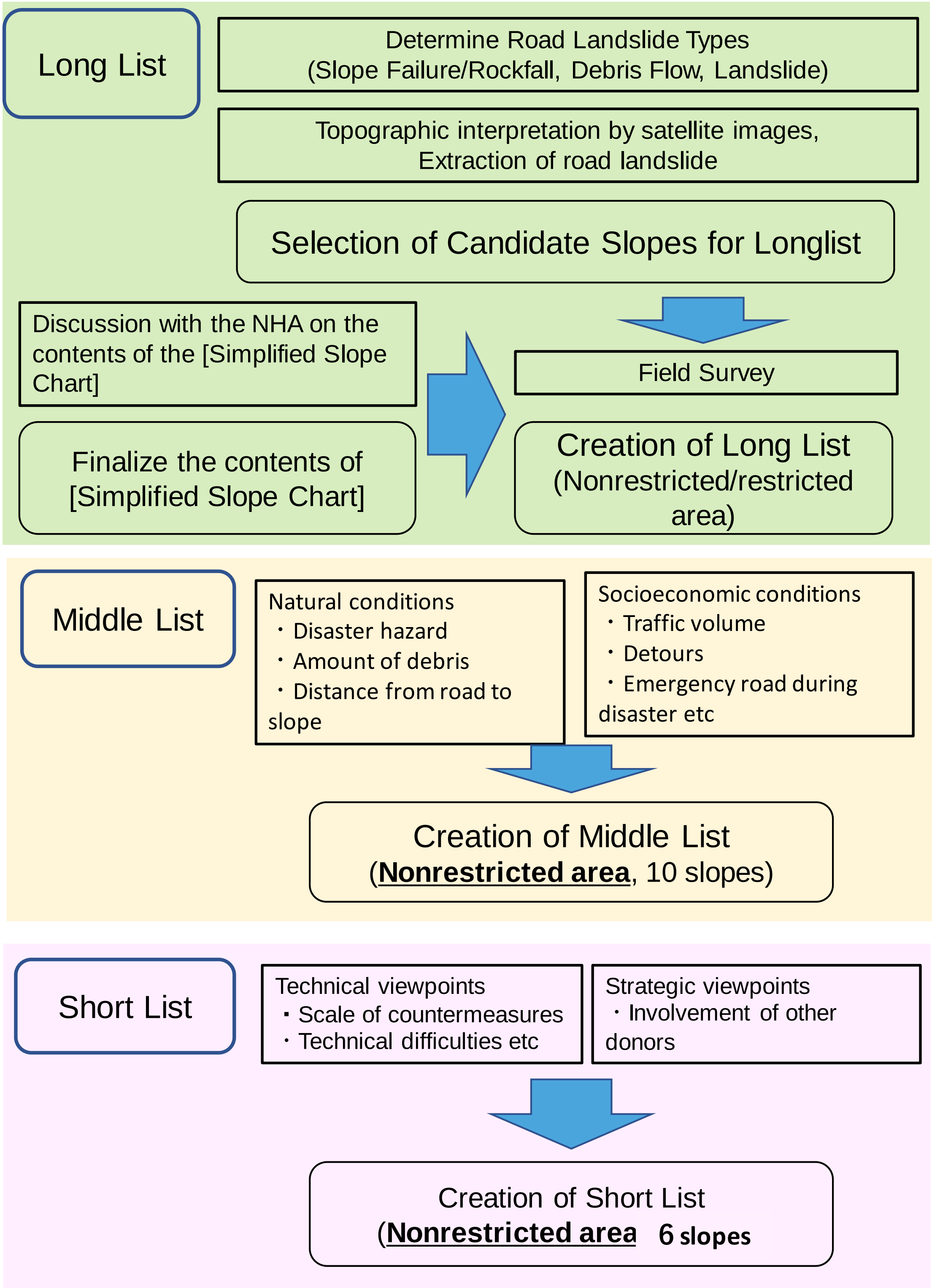


Figure 4.10 Flowchart of the Selections of Longlist, Middle List, and Short List

Source: JICA Survey Team

1) Overviewing of the Screening for Countermeasure Works Planning

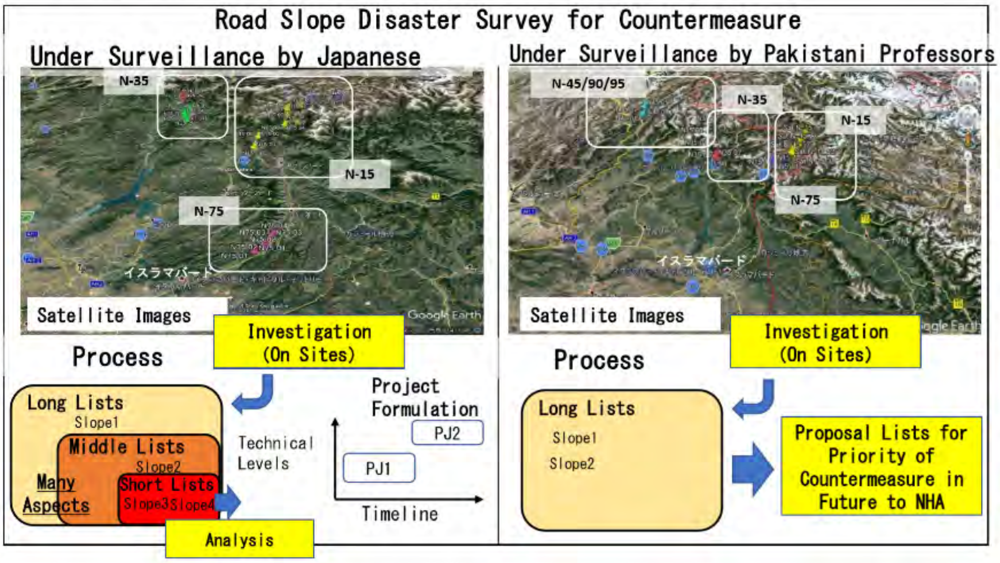


Figure 4.11 Process along Non restricted and Restricted Area

Source: JICA Survey Team

2) Methodology of Survey

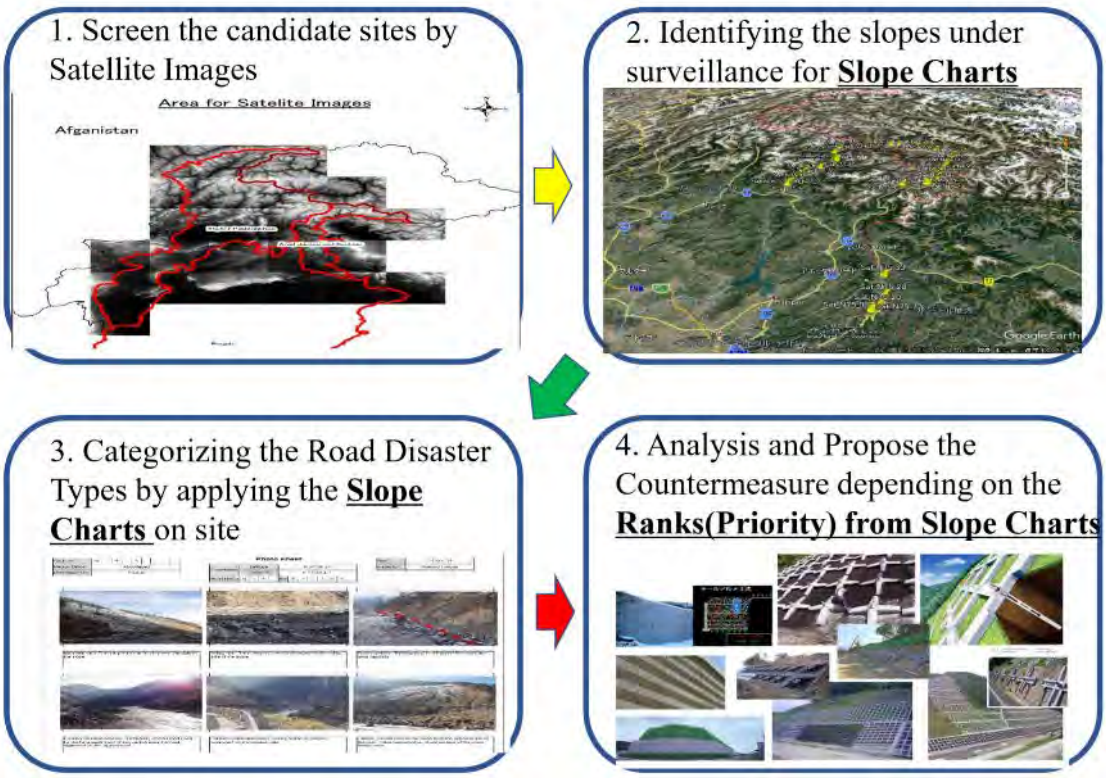


Figure 4.12 Specific Procedure from Interpretation to Proposal of Countermeasure Works

Source: JICA Survey Team

4.3 Long List

The survey target types of disaster (slope failure/rockfall, debris flow, and landslide) have been decided initially before the preparation of the long list[38].

Next, the candidate slopes (slope failure/rockfall, debris flow, and landslide) along the target national road was identified through the topography interpretation using satellite images (Rapid Eye) and Google Earth[39].

Based on the identified slopes from the topography interpretation, relatively large-scale slopes have been selected to form part of the candidate slopes for longlist. The simplified slope chart is prepared for each listed slope through the field survey. However, part of the study area (N15: north of Naran, N35: north of Besham, N75: north of Murree, N45, N90 and N95) cannot be accessed by JST owing to safety reasons. Therefore, the field survey for this area was outsourced to the Pakistani professors. The long list was prepared considering the result of the field survey (simplified slope chart) and the request from the NHA[40].

The figure below shows the non restricted and restricted areas.

[38] 4.3.1 Road Landslide Type
[39] 4.3.2 Topographic Interpretation
[40] 4.3.3 Field Survey using Simplified Slope Chart

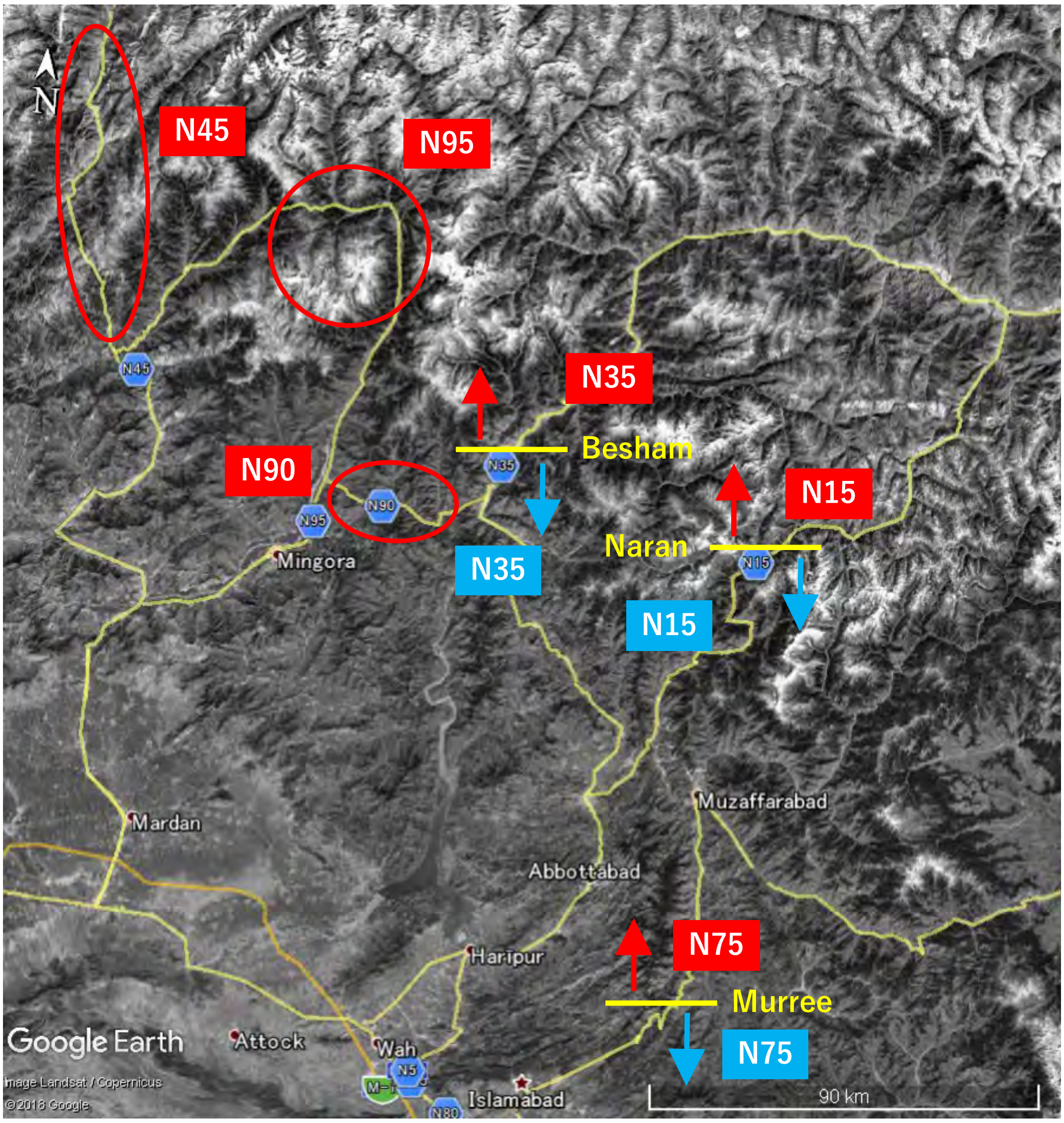


Figure 4.13 Location of Non restricted Area (Blue) and Restricted Area (Red)

Source: Google Earth

Figure 4.14 shows the flowchart of the preparation of the long List.

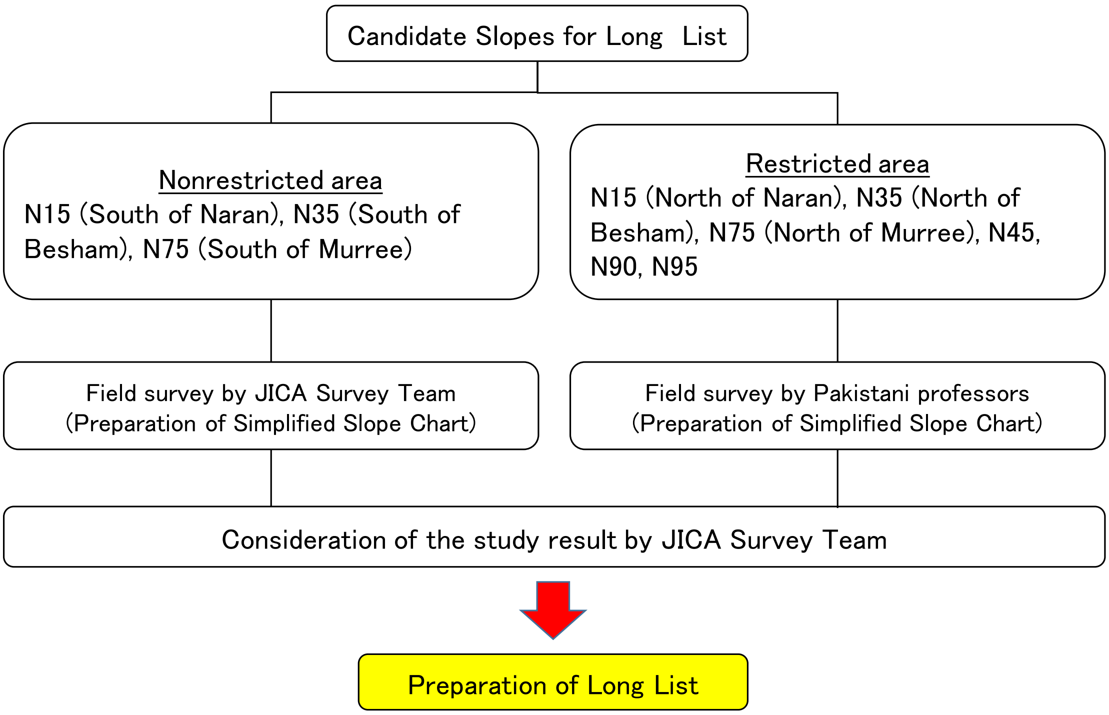


Figure 4.14 Flowchart of the Preparation of Long List Source: JICA Survey Team

4.3.1 Road Landslide Types

The road landslide types are divided into three types: landslide (in a narrow sense), slope failure, and debris flow; based on the existing reports and site reconnaissance in the preliminary stage of the study in the project. Images of the three types are shown in Figure 4.15.

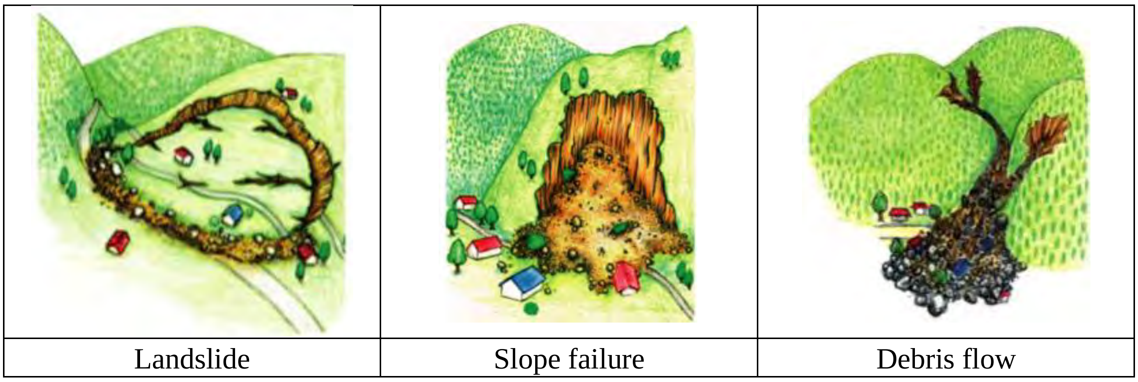


Figure 4.15 Schematic Images of Road Landslides Source: JICA Survey Team

There is a considerable amount of literature that defines the term “road landslide” or “landslide” (in a wide sense). The term “landslide” (in a wide sense) is defined by the United States Geological Survey (USGS), referring to Cruden[41] and Varnes[42], as follows:

[41] Cruden D. M., A Simple Definition of a Landslide. Bulletin of the International Association of Engineering Geology, No. 43, pp. 27–29, 1991
[42] Varnes D. J., Slope movement types and processes. In: Schuster R. L. & Krizek R. J. Ed., Landslides, Analysis and Control. Transportation Research Board Sp. Rep. No. 176, Nat. Acad. oi Sciences, pp. 11–33, 1978

A landslide (in a wide sense) is defined as "the movement of a mass of rock, debris, or earth down a slope"[*1]. Landslides are a type of "mass wasting" that denotes any down-slope movement of soil and rock under the direct influence of gravity. The term "landslide" encompasses events such as rock falls, topples, slides, spreads, and flows, such as debris flows commonly referred to as mudflows or mudslides[43]. Landslides can be initiated by rainfall, earthquakes, volcanic activity, changes in groundwater, disturbances and changes in a slope by man-made construction activities, or any combination of these factors.

The classification by Varnes[42] through the USGS is widely applied worldwide, and describes the updated classification.

Landslide, slope failure, and debris flow of classified road landslide types are as described in Figure 4.16 the following sections.

a. Landslide (in a narrow sense)

A landslide (in a narrow sense) is mainly equivalent to "slides". A landslide occurs in the slopes where the soil mass on one or more failure (slip) surfaces deep in the ground. The slipped land mass gradually shifts downward, triggered by heavy rain or an earthquake, river erosion, or earthworks. Landslides occur in areas with specific geological structure. The land mass moves forming specific topography (landslide topography) on a relatively large scale and the inclination of the landslide slope is relatively gentle in comparison with that of debris slope failure.

A landslide is a phenomenon in which clods of the slope slide under the influence of groundwater, etc. and it moves downward slowly. Landslides often occur under specific geological conditions.

b. Slope Failure

A slope failure is equivalent to "falls" and "topples" of rock mass, debris, and earth materials and it includes "rockfalls." In some cases, it consists of failures of rock mass detached to a steep slope/cliff along the surface with little or no shear displacement, which may be called a "surface failure," and failures of a mass of debris covering weathered and/or fractured bedrock. In comparison with landslides, slope failures move quickly and are small-scale and the inclination of a slope failure is relatively higher than that of a landslide.

A slope failure is a phenomenon in which the slope collapses rapidly owing to decreased resistance of the materials which constitute the slope, under the influence of rains, earthquakes, etc.

c. Debris Flow

A debris flow is equivalent to "flows" of debris and earth materials. A debris flow occurs in an area where soils and boulders are liquefied by surface water or groundwater and tend to flow downward rapidly through a mountain torrent. It usually has an enormous amount of energy and destructive force. Debris flows tend to occur in places where there are massive sediments of unstable debris along the steep torrent in the catchment basin. The risk of debris flows is relatively high in the catchment basin where slope failures often occur.

A debris flow is a phenomenon in which earth and sand flow down with waters, together with small

[43] Cruden D. M. and Varnes D. J., Landslide Types and Processes, in Turner, A. K., and R. L. Schuster, Landslides: Investigation and Mitigation, Transportation Research Board Special Report 247, National Research Council, Washington, D.C.: National Academy Press, 1996

to large boulders in general, along the mountain torrent, hillsides, and rivers. A debris flow is generally caused by heavy rains as well as rains of a long duration.

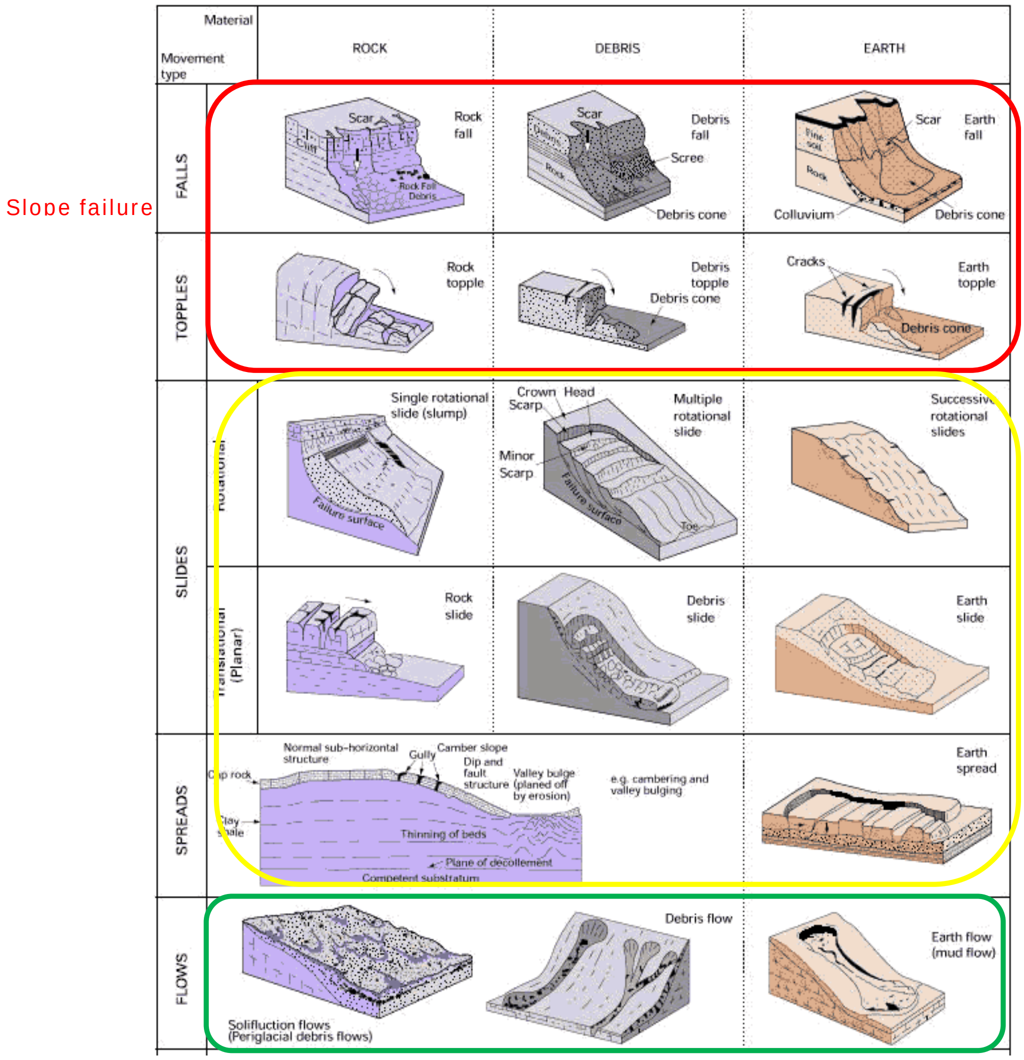


Figure 4.16 Relation between the Definition in USGS and the Phenomenon in this Report

Source: Modified after Varnes[44]

4.3.2 Topographic Interpretation

Satellite images (Rapid Eye) and Google Earth were used to identify the slopes along the road within the study area, as aerial photographs and topographic maps were not available. The anomaly (deformation of the slope, linear of the fault, etc.) was identified, followed by the classification of the disaster (slope failure/rockfall, debris flow, or landslide).

Google Earth has been used essentially for the topographic interpretation. However, part of the restricted area (northern area) could not be interpreted as its images was always covered with snow (period settings is limited for Google Earth). The satellite images (Rapid Eye) was used for certain parts of the restricted area (N15: north of Naran, N35: north of Besham, N75: north of Murree) to resolve this issue. Table 4.6 and Table 4.7 show the parameters of the images.

[44] Varnes D. J., Slope movement types and processes. In: Schuster R. L. & Krizek R. J. Ed., Landslides, Analysis and Control. Transportation Research Board Sp. Rep. No. 176, Nat. Acad. oi Sciences, pp. 11–33, 1978

Table 4.6 Parameters of Google Earth Images

Image	755 × 566 pixels
Resolution	1–15 m
Accuracy	4m (RMSE)
File Format	JPEG
Direction of image	Toward slope
Satellites	Earthsat, Digital Globe, Bluesky
Coordinate System	Geodetic: WGS84

Source: Google Earth

Table 4.7 Parameters of Rapid Eye Images

Image	Ortho (Level 3B)
Resolution	5 m
Accuracy	15 m (RMSE) 25 m (CE90)
File Format	GeoTIFF
Direction of image	Map north-up
Frame size	25 km × 25 km
Coordinate System	Geodetic: WGS84, Projection: UTM

Source: Webpage of Remote Sensing Technology Center of Japan

To identify slopes using Google Earth, the point or area with the characteristics of each disaster (slope failure/rockfall, debris flow, or landslide) was identified and numbered (Exp: N75_3). Figure 4.17 to Figure 4.19 show examples of the slopes identified by Google Earth.

The points or areas which ① have less vegetation than the surrounding and ② talus can be confirmed at the toe of the slopes were selected and identified as slope failures/rockfalls;

Figure 4.17 Example of Slope Identified by Google Earth (Slope failure/rockfall)

Source: Google Earth

the points or areas at which ① deposition of debris can be observed at the exit of the stream and ② slope failures can be confirmed along the stream were selected and identified as for debris flows;

Figure 4.18 Example of Slope Identified by Google Earth (Debris Flow) Source: Google Earth

and the points or areas at which ① landmass is detaching from the slope and forming a scarp and ② landslide topography (cross cracks, pressured ridges, etc.) can be confirmed were selected and identified as landslides.

Figure 4.19 Example of Slope Identified by Google Earth (Landslide) Source: Google Earth

The topographic interpretation of satellite images (Google Earth) was carried out utilizing ArcGIS software. The key points of each attribute (slope failure/rockfall, stream, debris flow, talus deposit, alluvial deposit, and lineament) are as mentioned below.

Slope Failure/Rockfall

<Generated area>

Identify the area where there is a deformation of landmass (center and top of the slope) and river erosion (toe of the slope). In case the area mentioned above could not be identified, the knick line zones shall be identified.

<Talus deposit>

Confirm the existence of the talus (half-conical sedimentary) at the toe of the slope failure/rockfall.

Generated area

Talus deposit

Figure 4.20 Interpretation Example of Slope Failure/Rockfall Source: JICA Survey Team

Stream (Debris Flow)

<Stream>

Identify the stream (valley) along the road until the possible generated area. Look for the zero-order basin or mountain top if the generated area could not be identified.

<Alluvial>

Confirm the debris (gentle gradient, fan-shaped) at the exit of the stream.

Stream | Alluvial deposit

Figure 4.21: Interpretation Example of Stream (Debris Flow)

Source: JICA Survey Team

Landslide

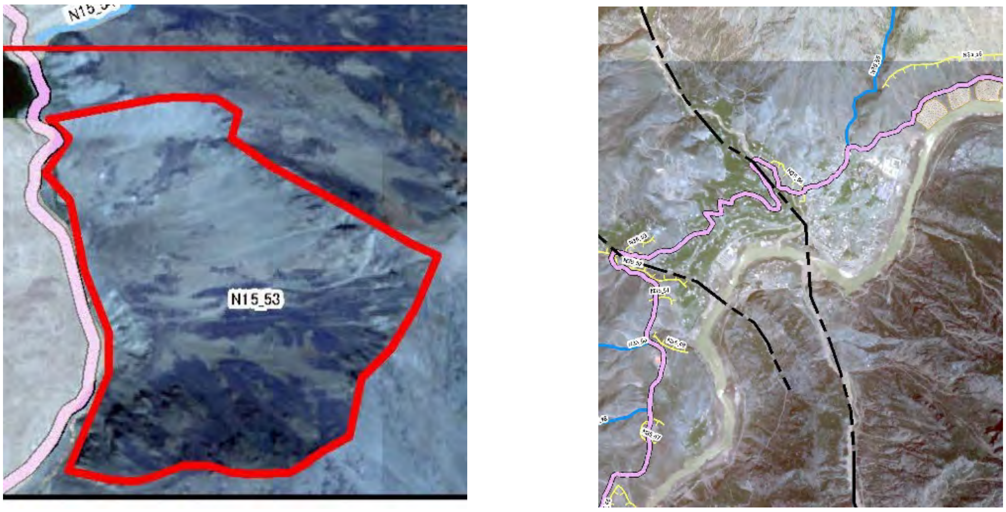
<Landslide mass>

Identify the landslide topography (scarps, stepped terrains, transverse cracks). If the landslide mass could not be identified, search for the contrast of topography with its surrounding.

Others

<Lineament>

Identify the line around the road within the satellite images.



Landslide | Lineament

Figure 4.22 Interpretation Example of Landslide and Lineament

Source: JICA Survey Team

Figure 4.23 shows an example of the interpretation result utilizing the satellite images based on the key points mentioned above (other areas are included in Appendix 1). The slope failure/rockfall, debris flow and landslide were numbered (Exp. Sat_N35_01).

Figure 4.23 Example of the Interpretation Result using Satellite Images

Source: JICA Survey Team

Preparation of list of Candidate Slopes for the Long List

The list of candidate slopes for the long list was prepared based on the result of the topographic interpretation. The criteria to be considered were: ① occurrence of disasters can be confirmed and ② scale of the disasters are relatively large.

Figure 4.24 shows the location of the candidate slopes of the long list and Table 4.8 shows the list of the candidate slopes for the long list for each road.

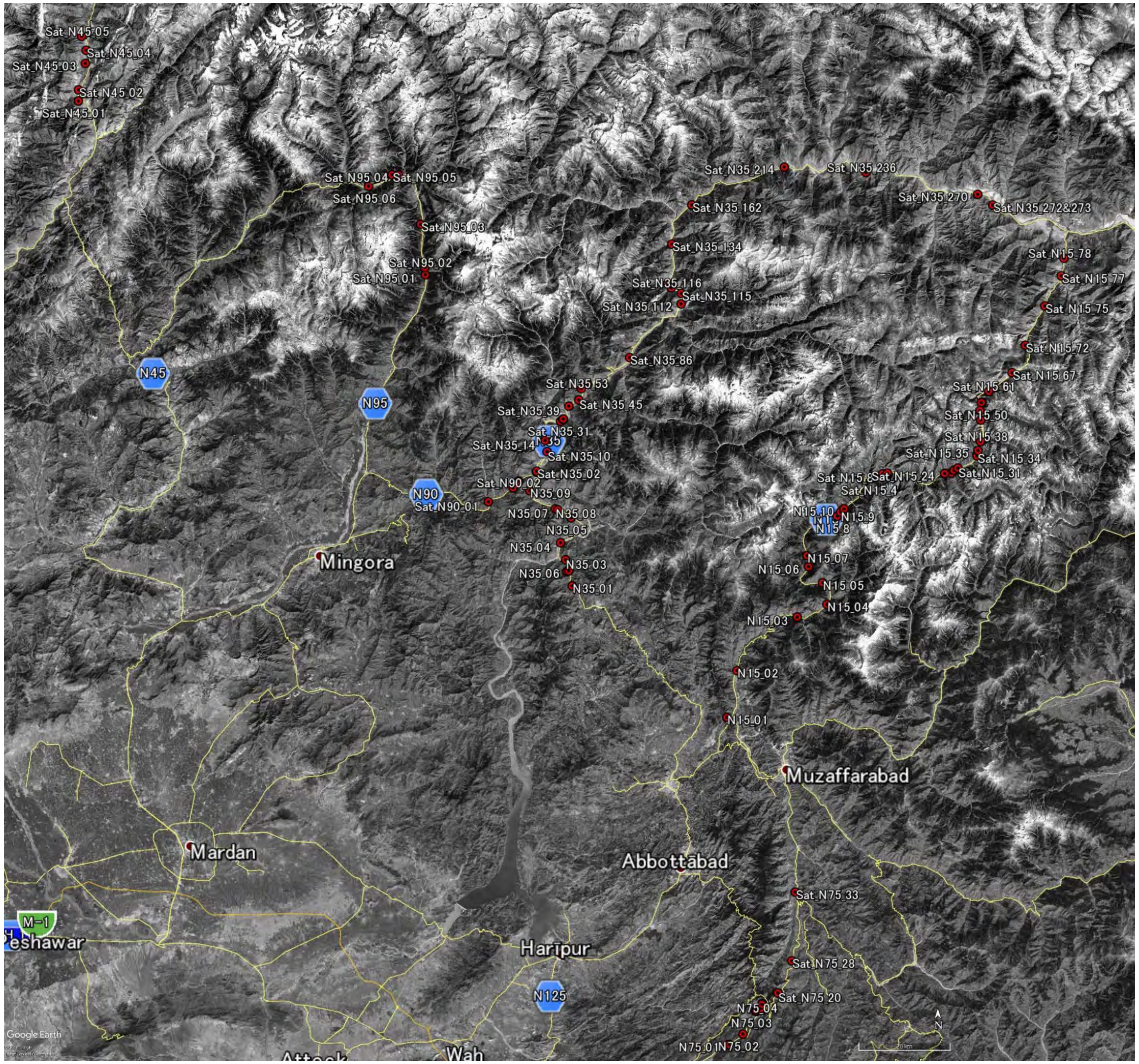


Figure 4.24 Location of Candidate Slopes of the Long List Source: Google Earth

Table 4.8 List of Candidate Slopes for the Long List

N15	Disaster
N15_01	Debris Flow
N15_02	Slope Failure
N15_03	Slope Failure
N15_04	Slope Failure/Debris Flow
N15_05	Debris Flow
N15_06	Slope Failure
N15_07	Debris Flow
N15_08	Debris Flow
N15_09	Debris Flow
N15_10	Debris Flow
Sat_N15_4	Landslide
Sat_N15_8	Debris Flow
Sat_N15_9	Debris Flow
Sat_N15_24	Slope Failure
Sat_N15_29	Debris Flow
Sat_N15_30	Slope Failure
Sat_N15_31	Debris Flow
Sat_N15_34	Debris Flow
Sat_N15_35	Slope Failure
Sat_N15_38	Debris Flow
Sat_N15_50	Debris Flow
Sat_N15_52	Debris Flow
Sat_N15_53	Landslide
Sat_N15_53-2	Landslide
Sat_N15_61	Debris Flow
Sat_N15_67	Debris Flow
Sat_N15_72	Debris Flow
Sat_N15_75	Debris Flow
Sat_N15_77	Debris Flow
Sat_N15_78	Debris Flow

N35	Disaster
N35_1	Slope Failure
N35_2	Slope Failure/Rockfall
N35_3	Debris Flow
N35_4	Debris Flow
N35_5	Debris Flow
Sat_N35_1	Slope Failure
Sat_N35_2	Debris Flow
Sat_N35_10	Debris Flow
Sat_N35_14	Slope Failure
Sat_N35_28	Slope Failure/Rockfall
Sat_N35_29	Slope Failure
Sat_N35_30	Slope Failure
Sat_N35_31	Slope Failure
Sat_N35_39	Debris Flow
Sat_N35_45	Slope Failure
Sat_N35_53	Slope Failure
Sat_N35_54	Slope Failure
Sat_N35_86	Slope Failure
Sat_N35_112	Rockfall
Sat_N35_115	Rockfall/Slope Failure
Sat_N35_116	Slope Failure
Sat_N35_119	Slope Failure
Sat_N35_134	Slope Failure
Sat_N35_162	Slope Failure/Rockfall
Sat_N35_214	Debris Flow
Sat_N35_236	Slope Failure
Sat_N35_270	Debris Flow
Sat_N35_272	Debris Flow

N75	Disaster
N75_1_1	Slope Failure
N75_2	Slope Failure
N75_3	Debris Flow
N75_4	Debris Flow
Sat_N75_7	Debris Flow
Sat_N75_9	Debris Flow
Sat_N75_20	Debris Flow
Sat_N75_28	Debris Flow
Sat_N75_33	Slope Failure

N45	Disaster
Sat_N45_1	Rockfall
Sat_N45_2	Rockfall
Sat_N45_3	Slope Failure
Sat_N45_4	Slope Failure
Sat_N45_5	Slope Failure

N90	Disaster
Sat_N90_1	Slope Failure
Sat_N905_2	Slope Failure
Sat_N905_3	Slope Failure
Sat_N90_4	Slope Failure
Sat_N90_5	Debris flow

N95	Disaster
Sat_N45_1	Slope Failure
Sat_N45_2	Debris Flow
Sat_N45_3	Debris Flow
Sat_N45_4	Slope Failure
Sat_N45_5	Debris Flow

Source: JICA Survey Team

4.3.3 Field Survey using Simplified Slope Chart

For the purpose of preparing the long list, a field survey was carried out for each candidate slope for the long list. As a tool for the field survey, the disaster inspection charts[45] used for the road inspection in Japan were modified to Pakistan simplified slope chart (hereinafter, slope chart), which is more adaptive to the conditions of Pakistan. The slope charts consist of three sheets, which are the evaluation sheet, sketch sheet, and photo sheet.

The evaluation sheet can be categorized into each disaster as shown below:

- Slope failure/Rockfall
- Debris Flow
- Landslide

The following figures show examples of the evaluation sheet (each disaster), sketch sheet, and photo sheet.

[45] Manual for Road Disaster Inspection (Japan Geotechnical Consultants Association, 2007)

Table 4.9 Example of Evaluation Sheet (Slope failure/rockfall) Source: JICA Survey Team

Evaluation sheet (Slope failure/Rockfall)

Code no.	N 1 5 _ 3
Region Office	Abbottabad
Maintenance Unit	Balakot

Coordinates	Latitude	N 34° 39' 27"
	Longitude	E 73° 30' 4.2"
Road name	N 1 5	Km 7 2 + 3 0 0

Date	14-Dec-17
Inspector	Makoto Tokuda

[Causes]

Item		factor	category of score	Check
topography	Collapsed factor	talus slope, clear convex break of slope, eroded toe of slope, overhang, water catchment slope	3 or more correspondences	✓
			2 correspondences	
			1 correspondences	
			no correspondence	
Geological conditions	Soil	susceptible to erosion less strength with water	marked	✓
			a little marked	
			None	
	Rock	high density of cracks and a weak layers, susceptible to erosion, fast weathering	marked	
			a little marked	✓
			None	
	Structure	dip slope of bedding plane	It corresponds.	✓
			None	
		debris on impermeability bedrock, the upper part is a hard /the toe of slope is weak.	marked	
			a little marked	✓
			None	
Surface codition	Topsoil, detached rock and unsteady rock		instability	✓
			a little unstable	
			stability	
	Spring water		notable spring waster	
			seepage	
			none	✓
	Surface condition		bare land with minor vagetation	✓
			intermediate (bare・grass・tree)	
			mainly structure, mainly tree	
Profile	Height (H), dip (i)		height: H≧50m	✓
			height: 30≦H＜50m	
			height: 15≦H＜30m	
			height: H＜15m	
			dip: i≧70°	
			dip: 45°≦i＜70°	
			dip: i＜45°	✓
Anomaly	Surface collapse, small fallen rock, gully, erosion, piping hole, subsidence, heaving, bending of tree root, fallen tree, crack, open crack, anomaly of countermeasure		2 or more correspondences・clarity	✓
			certain・unclarity	
			none	

[Disaster type]

Rock fall	
Slope failure	✓

[Main check object]

Cut slope	✓
Natural slope	

[Countermeasure]

Type of countermeasures	
Retaining wall	
Effectiveness of existing countermeasures	**Check**
Potential slope failure are prevented enough, or, it is defended enough when it is generated.	
Potential slope failure are considerably prevented, or it is considerably defended when it is generated.	
Potential slope failure are partly prevented, or it is partly defended when it is generated. However, it is not enough for the remaining factors.	
There is no countermeasure, or there is not effective even if countermeasures are not performed.	✓

[History]

Level of disaster history	Check
There is a history about large fallen rocks and slope failures that were obstacles to the road traffic after construction of recent measures.	✓
There is a history about large fallen rocks and slope failures that gets to the road though there is no obstacle to traffic.	
There is a history about small fallen rocks and slope failures that did not get to the road.	
No disaster records	

[Expected size of disaster](width, length, depth, etc.)

400m(w)*300m(h)*1m(d)=120,000m^3

[Hazard]

Hazard rank	A: the possibility of collapse/fall is high	✔
	B: the possibility of collapse/fall is moderate	
	C: the possibility of collapse/fall is low/none	

[Description]

The massive slope failure was triggered by the earthquake on 2013. Actual road is still buried 5m under the talus deposit. The removal of the talus deposit is still ongoing though it the work has to be done carefully as the small surface failure is continuously occuring at the site. Outcrop (quartzite, shale) can be observed from the scarp of the slope. By pass road were constructed on the opposite of the river though the long-sized truck has a difficulty due to road allignment. Optical fibre cable is buried at the mountain side of the bypass road.

Table 4.10 Example of Evaluation Sheet (Debris Flow) Source: JICA Survey Team

Evaluation sheet (debris flow)

Code no.	N 1 5 _ 5
Region Office	Abbottabad
Maintenance Unit	Balakot

Coordinates	Latitude	N 34° 43' 34.1"
	Longitude	E 73° 33' 36.4"
Road Name	N 1 5	Km 8 6 + 4 0 0

Date	13-Dec-17
Inspector	Makoto Tokuda

[Causes]

item	factor	category	Check
Property of river	areas that river bed is 15° or more in watershed area	$0.50km^2$ or more	✓
		$0.15km^2$ - $0.50km^2$	
		less than $0.15km^2$	
	steepest slope of river bed	40°or more	✓
		30° - 40°	
		less than 30°	
Property of slope	area that slope gradient is 30° or more in watershed area	$0.20km^2$ or more	
		$0.08km^2$ - $0.20km^2$	✓
		less than $0.08km^2$	
	area that meadow and shrub (less than 10m height) occupy in watershed area	$0.20km^2$ or more	✓
		$0.02km^2$ - $20km^2$	
		less than $0.02km^2$	
	artificial works that cause negative effects	certain	
		none	✓
	new crack and/or slope failure in stream	certain	
		none	✓
	traces of large slope failure in stream	certain	
		none	✓

[Road structure]

structure	category of score	Check
River width	10m or more	
	5m - 10m	✓
	3m - 5m	
	less than 3m	
Beam height	less than 1m or No bridge / box culvert	✓
	1m - 2m	
	2m - 3m	
	3m - 5m	
	5m or more	

[Potencial disaster mode]	Check
Damage of bridge/culvert	
Outflow of embankment	
Debris flooding on the road	✓

[History]

category of score	Check
There is a history about debris flow that were obstacles to the road traffic after construction of recent measures.	✓
There is a history about debris flow though there is no obstacle to traffic.	
There is no history of debris flow	

[Expected size of disaster] (width, length, depth, etc.)

200m(l)*3m(w)*2(d)=1,200m^3

[Countermeasure]

Type of countermeasure		Check
Retaining Wall		
Effect of existing countermesure	none・low	
	moderate	✓
	high	
	enough	

[Hazard]

Hazard rank:	A: the possibility of debris flow is high	✔
	B: the possibility of debris flow is moderate	
	C: the possibility of debris flow is low/none	

[Description/comments]

Continuous debris flow is reported in this site. According to the disaster record, the debris could cover 100m along the road.
Also, extra precaution shall be given for the big boulders located near the exit of the stream on the mountain side. Optical fibre cable is buried 1m at the mountain side of the road.

Table 4.11 Example of Evaluation Sheet (Landslide) Source: JICA Survey Team

Evaluation sheet (landslide)

Code no.	N	7	5	_	7				
Region Office									
Maintenance Unit	Murree								

Coordinates	Latitude	33,53,34.5									
	Longitude	73,24,38.0									
Road Name	N	7	5		Km	7					

Date	2017/12/9
Inspector	

[Main body of landslide]

Mountain side	
Valley side	
Both	√

[Countermeasure]

Category		Check	Type of countermeasure
There is no countermeasure			Retaining walls to protect road
Effectiveness of countermeasure	No effect		
	Some effect	√	
	High effect		

[Causes]

Category			Check
Topographical factor	Result of photo interpretation	exist clearly	√
		exist but partial and not clear	
		exist but not clear	
	Surface anomalies	large and new cracks, steps and subsidence	
		small and old cracks, steps and subsidence	
		slight deformation	√
		no anomalies	
Geological conditions	Geological structure	fault, fracture zone	
		dip slope	
		undip slope/ no characteristic feature	√
	Main rock formation of landslide body	metamorphic rock (schist, quartzite, phyllite etc.)	
		sedimentary rock (sandstone, limestone etc.)	√
		igneous rock (granite etc.)	
		quaternary deposit (colluvial deposit etc.)	
	Hydrological feature	much springs / much seepage	
		little springs /little seepage	√
		trace of water	
		no water observed	

[Evaluation Rank]

Hazard rank:	A: the possibility of debris flow is high	✔
	B: the possibility of debris flow is moderate	
	C: the possibility of debris flow is low/none	

[Expected size of disaster] (width, length, depth, etc.)

L= 1020 m, W= 650, D, 10-15 m

[History]

category			Check
Records of Landslide	Existing record (documents or patrimony)	obvious	√
		slight	
		none	
	Damage on road facilities and houses	obvious	
		slight	√
		none	

[Description]

The landslide N-75-7 along the Murree expressway, is an old landslide with around 3 km2 area . Lithology of the site is characterized by claystone, siltstone and sandstone of the Miocene Murree Formation. The visible scarp of the landslide indicates this as an old landslide,and has been reactivated many time in the past, consequently, small landslides were also observed within the landslide. The upper part of the slide is stable, however, the toe of the landslide material is active with potential for future landslide. The right side of the slide is reactivated and can be considered as potential threat to the road in future. Although, the reatining walls is already built to protect the road. However,the displacement upto 4 cm has been observed also in the retaing wall.

Table 4.12 Example of Sketch Sheet Source: JICA Survey Team

Sketch sheet

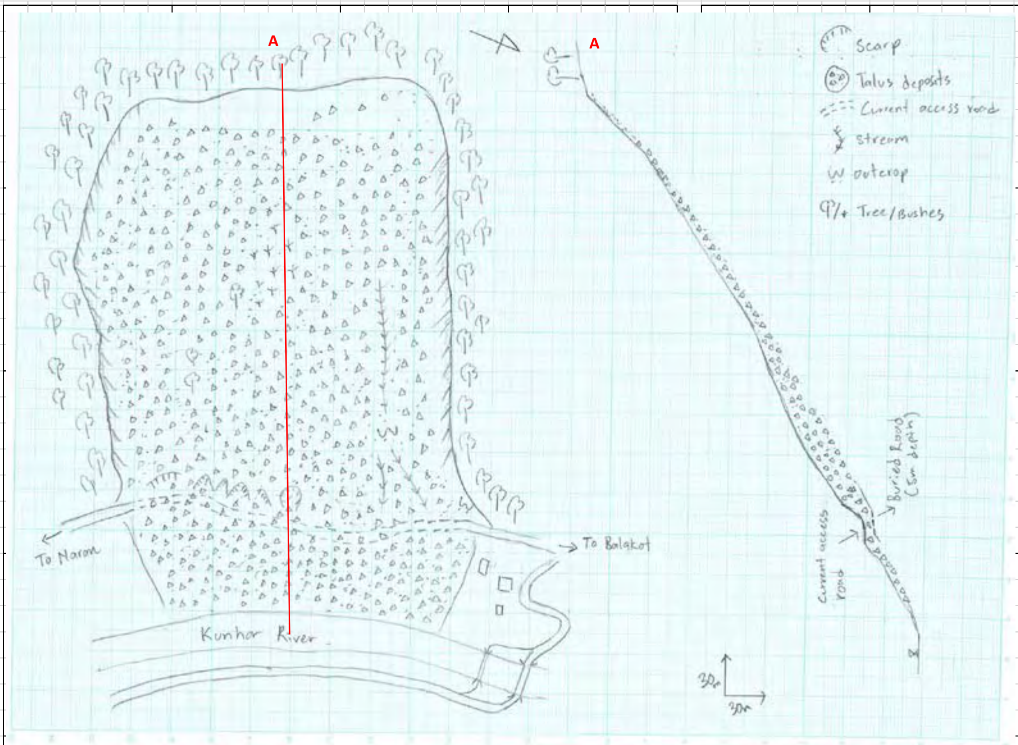
Code no.	N 1 5 _ 3
Region Office	Abbottabad
Maintenance Unit	Balakot

Coordinates	Latitude	N 34°39' 27"
	Longitude	E 73°30' 4.2"
Road Name	N 1 5	Km 7 2 + 3 0 0

Date	14-Dec-17
Inspector	Makoto Tokuda

Plane view

Cross sectional view



Scale: ← ( ) m →

Scale: ← ( ) m →

Table 4.13 Example of Photo Sheet Source: JICA Survey Team

Photo sheet

Code no.	N 1 5 _ 3			Date	14-Dec-17
Region Office	Abbottabad	Coordinates: Latitude	N 34°39' 27"	Inspector	Makoto Tokuda
Maintenance Unit	Balakot	Coordinates: Longitude	E 73°30' 4.2"		
		Road Name	N 1 5 Km 7 2 + 3 0 0		

Overall view of the slope from the opposite site of the river. Talus deposited on whole surface of the slope failure area.

Valley side: Talus deposits can be observed on the valley side of the slope.

Road condition: Existing road is still buried 5m under the talus deposits.

Existing countermeasures: Temporary access road used for the long-sized truck which cannot pass the road alignment on the bypass road.

Existing countermeasures: Bailey bridge is used as temporary on the bypass road.

Mountain side: Talus deposits can be observed throughout the slope.

a. Method of Field Survey

Field surveys were carried out for the Candidate Slopes of Long List by the JICA Survey Team (in the non restricted area) and Pakistani professors (in the restricted area). Each Pakistani professor has a major in geology and is well experienced in field surveys of road landslides. In addition, they have participated in OJT of preparing the Simplified Slope Chart conducted by the JICA Survey Team. Therefore, there are no problems regarding the quality of the Simplified Slope Chart prepared by the Pakistani professors.

Table 4.14: Pakistani Professors

Name	Organization	Position
Muhammad Basharat	Institute of Geology, University of Azad Jammu and Kashmir, Muzaffarabad, Pakistan	Associate Professor
Yasir Sarfraz		
Sajid Ali	RWTH Aachen University, Germany	Neotectonics & Natural Hazards Group
Muhammad Shafique	National Center of Excellence in Geology, University of Peshawar, Peshawar, KPK, Pakistan	Assistant Professor

Source: JICA Survey Team

Figure 4.25 Shows the study areas of the JICA Survey Team and Pakistani professors.

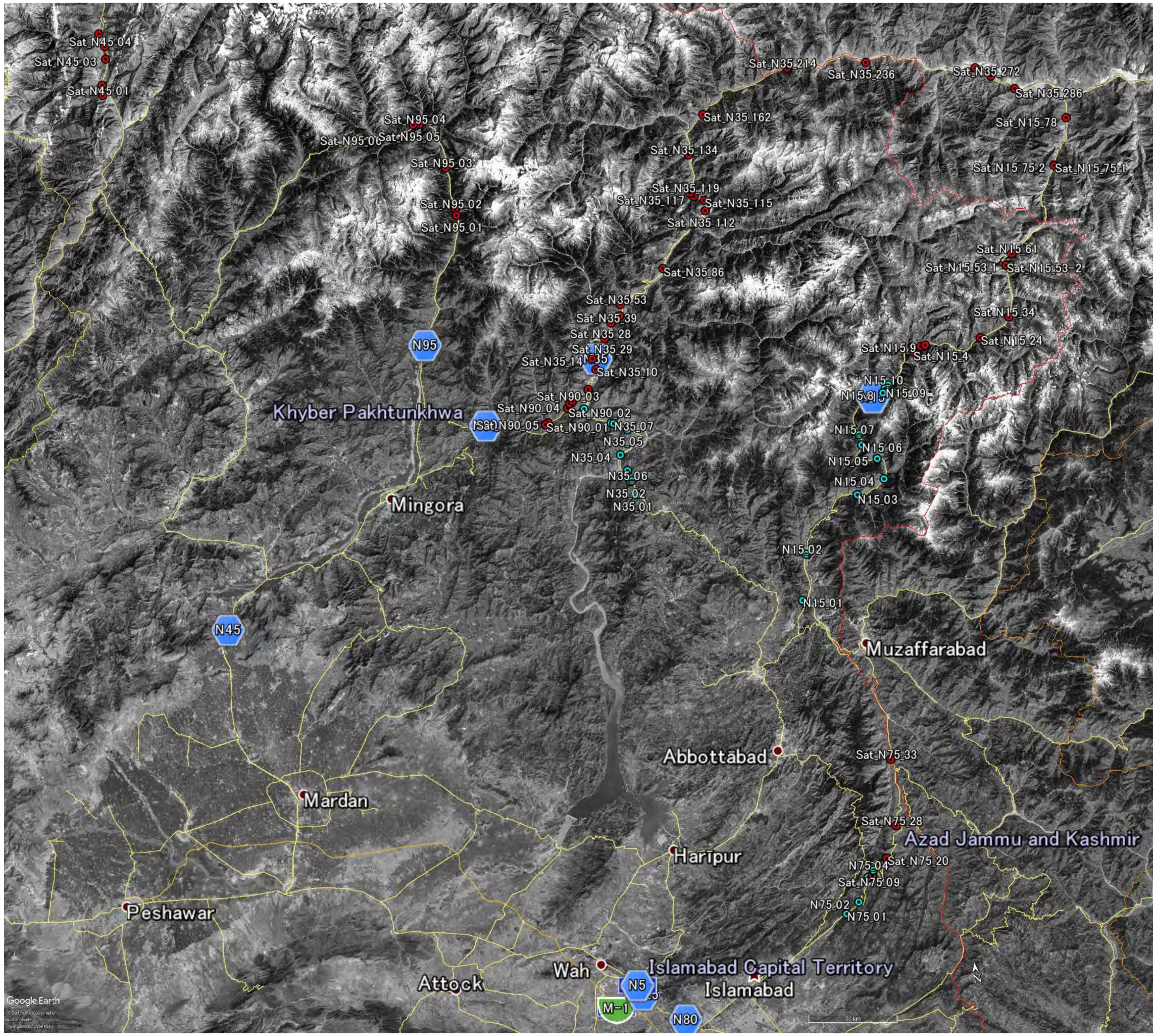


Figure 4.25 Study Areas of JICA Survey Team (Blue) and Pakistani Professors (Red)

Source: Google Earth

In general, the field survey is carried out through visual confirmation using the simplified slope chart. In the case of the situations below, the survey was carried out using other methods as shown below:

1) Area of basin, vegetation and generated area of debris flow: Ruler of Google Earth

2) Gradient of debris flow: Estimation of elevation by Google Earth

3) Situation of the slope of debris flow: Confirmation by Google Earth (image interpretation)

4) Disaster record: Interview with the NHA

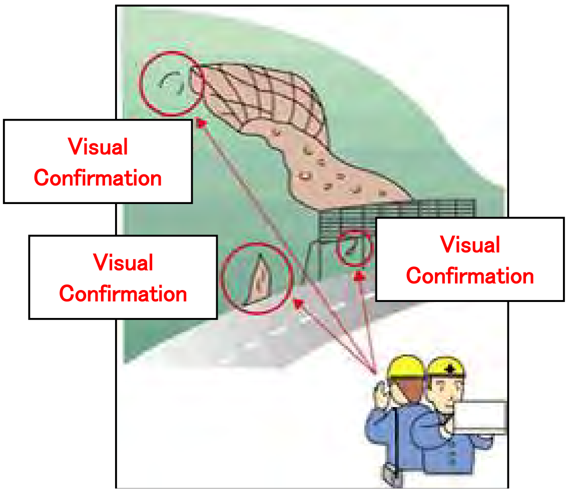


Figure 4.26 Methods of Field Survey
Source: West Japan Engineering Consultants Inc.

Table 4.15 shows the common items of the Simplified Slop Chart and Table 4.16 to Table 4.18 shows its items by each disaster.

Table 4.15 Items of Simplified Slope Chart (Common)

Items	Contents
Basic (inspector, date)	Insert the information of the inspector of the chart and date
Position (road, coordinate)	Insert the position information as the third party could understand
Management (jurisdiction)	Insert the information as the responsible unit can be identified
Cause and factor	Mark the deformation and characteristic of the disaster
Existing countermeasure and its effectiveness	Insert the type of existing countermeasure and its effectiveness
Disaster Record	Insert the disaster record and the scale
Expected size of disaster	Insert the expected size of the disaster
Description	Insert the description or comments which are not included in the items
Evaluation rank	Evaluate based on the hazard and scale of disaster

Source: JICA Survey Team

Table 4.16 Items of Simplified Slope Chart (Slope failure/rockfall)

Items	Contents
Disaster type and main check object	Insert disaster type (rockfall/slope failure) and main check object (cut slope/natural slope)

Source: JICA Survey Team

Table 4.17 Items of Simplified Slope Chart (Debris Flow)

Items	Contents
Potential disaster mode	Select the potential disaster from the item
Road structure	Insert the river width and beam height

Source: JICA Survey Team

Table 4.18 Items of Simplified Slope Chart (Landslide)

Items	Contents
Main body of landslide	Select the main body (mountain, valley, both) of the landslide

Source: JICA Survey Team

b. Range and Points of Slope Chart Preparation

The slope chart was prepared for the potential road disasters, which are slope failures/rockfalls, debris flows, and landslides. The points to be considered during the preparation of the slope chart are mentioned below.

b.1 Range

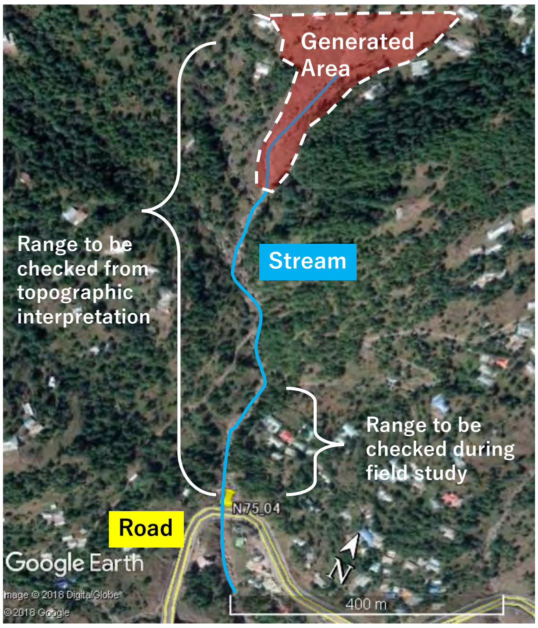
The range to be checked are different for each type of disaster.

Table 4.19 Outline of the Range to be Checked

Disaster	Contents
Slope failure/ Rockfall	In general, the range to be checked is up to the generated area if the topography was remarkable during the interpretation and has a threat to the road. However, the results of topographic interpretation can be used if the access is limited at the site.
Debris Flow	The range to be checked is up to the generated area if the topography was remarkable during the interpretation and has a threat to the road. However, the result of topographic interpretation can be used if the access is limited at the site. If the generated area could also not be identified from the topographic interpretation, check the situation of the debris in the river as much as possible. Then, combine the results of the field survey and desk study.
Landslide	The range to be checked is the area which are remarkably present the landslide topography (deformation of toe, etc.) from the topographic interpretation. However, the result of topographic interpretation can be used if the access is limited at the site.

Source: Japan Geotechnical Consultants Association

Slope failure/Rockfall



Debris Flow

Landslide

Figure 4.27 Range of Field Survey of each Disaster

Source: Google Earth

b.2 Points to be Checked

b.2.1 Slope failure/Rockfall

Points to be checked for the slope failure/rockfall are as mentioned below.

<Topography>

Peculiar topography (scarp, knick line, overhang, catchment slope) or a topography that could promote the failure can be observed where the slope failure/rockfall is relatively active. Therefore, an area with a remarkable topography of above can be judged as slope failure/rockfall.

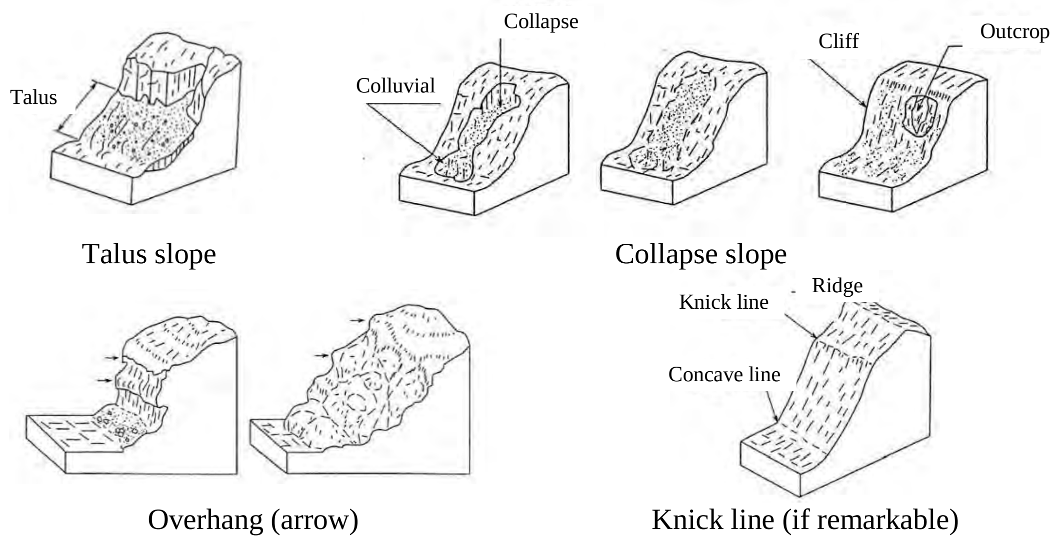


Figure 4.28 Typical Topography of Slope Failure/Rockfall

Source: Japan Geotechnical Consultants Association

<Soil, Geology, and Structure>

The characteristics of the soil, geology, and structure for which the slope failure/rockfall is likely to occur (fast cycle of failure) are as mentioned below.

Soil: vulnerable to erosion, strength degradation with water.
Geology: High density of weak layers and fractures, soft rocks that are vulnerable to erosion, fast weathering.
Structure: Dip slope, landmass on the impermeable base, hard rocks on top/weak at the toe.

<Surface Condition>

Check the ① top soil, detached/hanging rock, ② springs, and ③ condition of the cover soil.

<Shape (gradient and height of cut/natural slope)>

The stability of the slope is low when the gradient becomes steeper and the height increases (if the topography, geology, and hydraulic conditions are similar).

<Deformation>

The stability can be estimated by checking the deformation (small rocks, gully erosion, scour, piping hole, cracks, etc.) of the cut/natural slope.

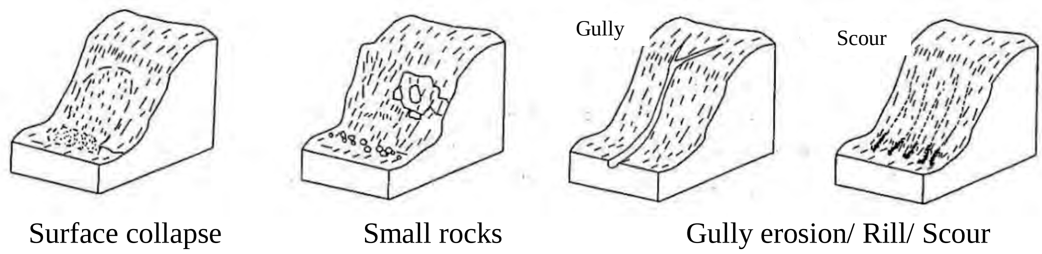


Figure 4.29 Typical Deformation of Slope Failure/Rockfall

Source: Japan Geotechnical Consultants Association

<History of Disaster>

If the slope failure/rockfall had occurred after the construction of a recent countermeasure, judge by the frequency and impact to the traffic.

b.2.2 Debris Flow

The points to be checked for the debris flow are as mentioned below.

<Characteristic of Stream>

The gradient of the river bed of the generated area shall be more than 15 (utilize the ruler from Google Earth). The result of the topographic interpretation can be utilized if the generated area could not be accessed at the site. The result of topographic interpretation can also be utilized to estimate the steepest angle of the river bed (estimation of the elevation by Google Earth).

<Characteristic of Slope>

Confirm the area where the slope gradient is steeper than 30, area w meadows and shrubs (less than 10 m height) occupy in the watershed area, presence of the cracks and slope failures in the past during a site survey. The result of topographic interpretation can be utilized if the site could not be accessed (utilize the ruler from Google Earth). Regarding the presence of artificial structures on unstable ground, confirm the point where the artificial structure is constructed on the river bed is steeper than 15 and the ground is unstable. The result of topographic interpretation can be utilized if the site could not be accessed (utilize the ruler from Google Earth).

<Road Structure>

Confirm the condition of the debris under the bridge/beam, inside the box culvert, river width and beam height. The beam height means the height from the river bed to the road facility. In case of a box culvert, read the inner height of the box culvert.

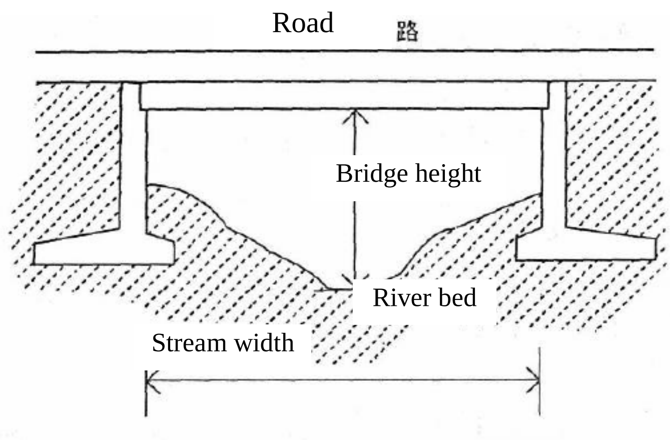


Figure 4.30 Definition of Beam Height and River Width

Source: Japan Geotechnical Consultants Association

<Potential Disaster Mode>

Categorize the potential disaster that could affect the road and road structure near the exit stream.

- Damage of bridge/culvert

- Outflow of embankment
- Debris flooding on the road

b.2.3 Landslide

The points to be checked for the landslide are as mentioned below.

<Landslide Topography>

Landslides can be divided into the re-activate type (landslide topography can be observed as the movement of the landmass reactivated) and primary type (landslide topography cannot be observed). The frequency of the re-activate type is higher than the primary type. Therefore, it is important to understand the topography of the landslide.

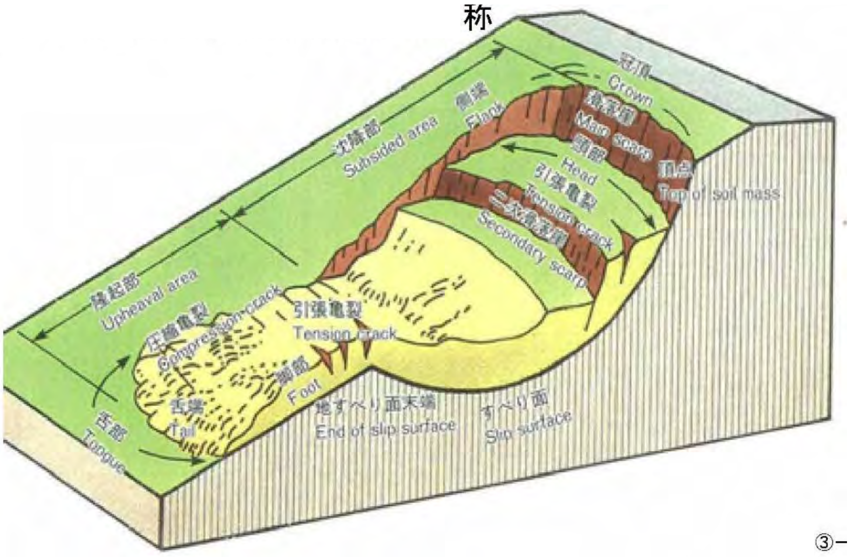


Figure 4.31 Typical Landslide Topography

Source: J. Varnes, 1958

<Geology>

Landslides often occur under similar geological characteristics, such as tertiary zone, fracture zone, and volcanic alteration zone. Therefore, it is important to understand the geology related to the landslide occurrence.

<History of Landslide>

Generally, a landslide tends to occur periodically and recurrently. Therefore, the study of its history is important in estimating the future occurrence of the landslide.

<Symptom of Landslide>

The microtopography such as cracks, subsidence, and upheaval can be confirmed when the landslide becomes active.

c. Result of Field Survey

After conducting the field survey, the area that could not be trespassed was excluded from the list of candidate slopes for the long list. The site excluded is mentioned below:

N35_4: The bridge constructed by China is generally prohibited to trespass (by foot).

Five slopes were added to the list of candidate slopes for the long list, as requested by the NHA during the field survey. The sites added are mentioned below:

N35_6: Slope failure occurred in November 2017 and affected road traffic.
N35_7: Rockfall occurred on 18th December 2017.
N35_8: The site could not be identified during the topographic interpretation. The cracks were observed on the detached rock located on top of the road, which could fall at any time.
N35_9: Debris flow occurred every rainy season. In 2017, it blocked the road for several weeks.
N75_5: The site could not be identified during the topographic interpretation.

Table 4.20 shows the final number of the planned candidates slopes for the long list. Each result from the long list is shown in Table 4.21. Figure 4.32 shows the location of the field survey.

Table 4.20 Status of Covered Slopes for Long List

Road	Non restricted area		Restricted area	
	Plan	Actual	Plan	Actual
N 15	10	10	10	10
N 35	5	9	25	25
N 45	0	0	5	5
N 75	5	6	5	5
N 90	0	0	5	5
N 95	0	0	5	5
Total	**20**	**25**	**55**	**55**

Source: JICA Survey Team

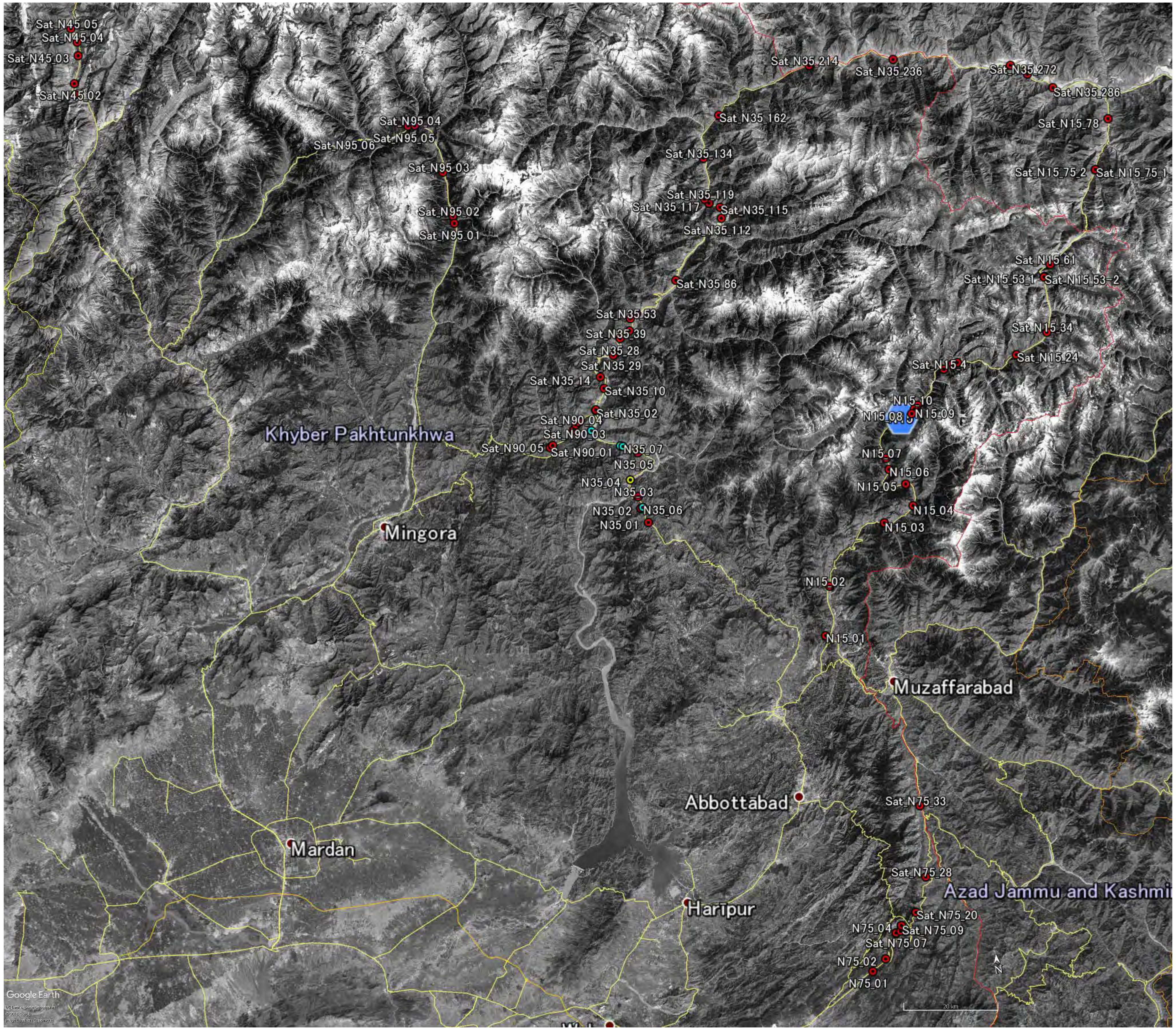


Figure 4.32 Location of the Field Survey (Red: Planned, Green: Added, Yellow: Deleted) Source: Google Earth

Table 4.21 Long List Source: JICA Survey Team

No.	Disaster	Disaster Record	Cause	Geology (if any)	Remarks	Hazard
N15_1	Debris flow+Slope Failure	b	The drainage underneath the road is narrow (small) which may cause deposition of sediment on the road	Metamorphic rocks of Lower Himalaya	・Large boulders along the stream with relatively gentle angle of river bed. There is a trace of old slope failure vegetation at along the stream.	b
N15_2	Slope Failure	c	The slope consist of fractured metamorphic rock and has became unstable due to weathering and infiltration of rain water into the soil.	Metamorphic rocks of Lower Himalaya (Quartzite, Slate)	・Relatively large slope failure with vegetation. There are buliding (restaurant) at the toe of the slope.	c
N15_3	Slope Failure	a	The slope consist of fractured metamorphic rock and has became unstable due to weathering and infiltration of rain water into the soil.	Metamorphic rocks of Lower Himalaya (Quartzite, Slate, Phylite)	・A very large slope failure triggered in 2013 earthquake. There is necessity to re-open this road as the long vehicle could not go through the by pass. ・Removal of the deposit has been ongoing though the surface failure keep occuring.	a
N15_4	Slope failure+Rockfall	c	The slope consist of fractured metamorphic rock and has became unstable due to weathering and infiltration of rain water into the soil.	Metamorphic rocks of Lower Himalaya (Slate)	・Continuous surface failure is expected due to erosion	b
N15_5	Debris Flow	a	The debris may reach the road during rainfall	Metamorphic rocks of Lower Himalaya	・Large boulders deposited at the exit of the stream. Several disaster in which debris flooded the road cousing road closure.	a
N15_6	Slope Failure	a	The slope consist of fractured metamorphic rock and has became unstable due to weathering and infiltration of rain water into the soil.	Metamorphic rocks of Lower Himalaya (Schist, Gneiss)	・Continuous talus deposition on the road, damage on the gabion and retaining wall and road subsidence was confirmed at the site.	a
N15_7	Debris Flow	c	The bridge (Bailey bridge) may be damaged due to river erosion during rainfall	Metamorphic rocks of Lower Himalaya	・Bailey bridge is built passing the stream and countermeasure for the erosion of the bank is applied near the bridge.	c
N15_8	Rockfall	a	The detached boulders on the steep scarp may result a rockfall on the road	Metamorphic rocks of Lower Himalaya	・There are records that large fallen rocks happened and were obstacles to the road traffic. The retaining wall has no effect as a countermeasure for rock falls.	a
N15_9	Slope failure+Rockfall	a	The fractured and weathered surface of the slope causing the slope failure	Metamorphic rocks of Lower Himalaya (Schist)	・Slope failure happens and reached to the road every day, and is remarkable after rainfall (by NHA). The existing retaining wall is not enough to protect the road from the failure.	a
N15_10	Debris Flow	a	Debris, sand and rocks, which could be debris flow, are filled on the river. Surface water and debris are continuously flowed out to the road, especially in snow melting season.	Metamorphic rocks of Lower Himalaya	・The river crosses on the road. In winter season, glacial mass from the upper side of the river moves downward and covers the road.	a
Sat_N15_4	Landslide	a	It is an old rotational landslide which has been reactivated due to road construction and rainfall.Many detached boulders are hanging on the landslide scarp that can damage the road and the continuity of traffic	Granite and Schist	・The upper part of the landslide is stable with vegetation cover, however, the landslide is active at the toe.	b
Sat_N15_8	Debris Flow	a	Debris flow origin appears from the glacier valley has a large amount of water in the channel posing great and frequent risk t	Boulders, cobble, gravel, sand and silt	・Size of the boulders ranges upto $5m^3$. A very serious debris flow disaster occurred after every five years at the site.	b
Sat_N15_9	Debris Flow	a	The debris material from the narrow channel might be active during the rainfall and can also lead to a debris flow disaster in	Boulders, cobble, gravel, sand and silt	・A retaining wall is constructed to protect the road which is also partly damaged.	b
Sat_N15_24	Slope Failure	c	An active erosion on the slope leads to the development of the gullies.	Metamorphic rock	・Retaining wall is built to protect the road though no mitigation measures taken to stabilize the slope failure.	c
Sat_N15_34	Debris Flow	a	An active debris flow with large catchment area and contunously supplying a great amount of water.		・About 60 meters road has been damaged due to this debris flow.	a
Sat_N15_53_	Landslide	a	Presently, this rock avalanche has no impact on the road though it may block the water channel and disrupt the road.	Granite and Gneisses	・An old rock avalanche which triggered due to any tectonic activity in the ancient time creating Lalusar Lake	a
Sat_N15_61	Debris Flow	a	Debris flow has very large surface run off with steep gradient. Due to this steep gradient, debris flow posing serious debris flow disaster which cause to damage the road and discontinuity of the traffic		・Culvert is constructed for the out flow of the water, however, it does not fulfill the requirement. ・The active landslides were also observed both side of the river bed along the road posing risk to damage the road.	a
Sat_N15_75_	Debris Flow	a	Debris flow has very long run-out and transported a huge debris material which covered the entire road section.	Gabbro diorite and Granitic rocks	・ Debris flow event occurred in July 2017 due to a very heavy rainfall in the area.	a
Sat_N15_75_	Debris Flow	a	The source of the debris flow has very steep cliff. Large number of boulders are still hanging along the road that lead to furth	Gabbro diorite and Granitic rocks	・ Debris flow event occurred in July 2018 due to a very heavy rainfall in the area.	a
Sat_N15_78	Slope failure	a	Unconsolidated debris material is present both sides of the erosional channel and prone to disaster.		・No countermeasures have been taken to avoid the debris material on the road.	b
N35_1	Slope failure+Rockfall	b	The slope consist of fractured metamorphic rock and has became unstable due to weathering and infiltration of rain water into the soil.	Metamorphic rocks of Higher Himalaya (Schist)	・Shotcrete & retaining wall (with piling) is constructed at the old slope (5 years ago by FWO) However, no effective countermeasure is being done for the new slope failure which occurred two years ago. Currently, CPEC is changing the road alignment to the valley side.	b
N35_2	Slope failure+Rockfall	c	The slope consist of fractured metamorphic rock and has became unstable due to weathering and infiltration of rain water into the soil.	Metamorphic rocks of Higher Himalaya (Schist)	・Combination of slope failure and rockfall. Vertical cracks is observed on the slppe with a possibility of rockfall.	c
N35_3	Debris Flow	b	The debris along the stream is caused by the blasting. The debris may flow toward the road during the rainfall.	Metamorphic rocks of Higher Himalaya (Crystalline Schist, Quartzite, Slate)	・Stream was used for blasting by CPEC to collect construction materials ・Big boulder is overhanging near the road which need to to be removed.	c
N35_4	Debris Flow	c	This site was excluded as it has been already taken care by the Government of China	Metamorphic rocks of Higher Himalaya	・New bridge was built to replace old suspension bridge (not because of erosion of the foundation) ・Sensitive area for the security reason (check post is on the both side of the bridge)	c
N35_5	Debris Flow	b	The debris may flow toward the road during the rainfall.	Metamorphic rocks of Higher Himalaya	・Stepped (terrace) shaped stream at the exit with some clearance (22m) before the road.	c
N35_6	Slope Failure	c	The slope consist of fractured metamorphic rock and has became unstable due to weathering and infiltration of rain water into the soil.	Metamorphic rocks of Higher Himalaya (Slate, Schist, Gneiss)	・Continuous surface failure occurred from 3 years ago due to erosion/weathering (additional site requested by NHA).	b
N35_7	Rockfall	b	The slope consist of fractured metamorphic rock and has became unstable due to weathering and infiltration of rain water into the soil. The detached rock is hanging on top of the road and the probability of the rockfall is very high.	Metamorphic rocks of Higher Himalaya (Slate, Phylite)	・Additional site requested by NHA. ・A very unstable rock is overhanging on the road with cracks.	b
N35_8	Rockfall	a	The slope consist of fractured metamorphic rock and has became unstable due to weathering and infiltration of rain water into the soil.	Metamorphic rocks of Higher Himalaya (Slate, Phylite)	・Additional site requested by NHA. ・Several rock fall occurred within two weeks (may keep occur until the rocks stablize).	a
N35_9	Debris Flow	a	The amount of debris is very large despite the gentle angle (<15°) of the stream. These debris is supplied from the erosion of the riverbed.	Metamorphic rocks of Higher Himalaya	・Large amount of debris flooding the road every year during rainy season (additional site requested by NHA). ・Large portion of debris are supplied from the erosion of the stream bed.	a
Sat_N35_1	Slope failure	b	This slope is actually cut slope due to excavation for N35 and link road above the scarp	Metasedimentary(Besham group)	・Retaining wall is partly damaged	b
Sat_N35_2	Debris Flow	b	Small catchment area with debris fall/rock fall material are present on the upstream. Small landslide was also observed along the stream which contribute in the debris volume.	Granite	・The culvert has been blocked due to debris material along this channel	b
Sat_N35_10	Debris Flow	a	The water seeps beneath the road and through could lead to potential disaster and significant damages to the road	Granitic rock	・ It is a historically active debris flow with continuous flowing water	b
Sat_N35_14	Slope failure	a	The slide was mainly triggered during the 2005 earthquake and also reactivated during the torrential and prolonged monsoonal rains of 2010.	Granitic rock	・The scarp and upper parts of the slope is partially stable with thick vegetation	a

No.	Disaster	Disaster Record	Cause	Geology (if any)	Remarks	Hazard
Sat_N35_28	Slope failure	a	Detached boulders and gravels are hanging on the slide that combine with the sand and silt leads to debris flow during the rainy season.	Pyroxinite	・Retaining wall is constructed to stabilize the slide, however, the right side of the retaining wall is already damaged.	a
Sat_N35_29	Rockfall	a	Boulders and gravels were detached and hanging on the slide and therefore posing threats to the road and traffic.	Pyroxnitic rocks	・Talus is visible at the slide toe.	b
Sat_N35_30	Rockfall	a	Detached and hanging boulders and gravels were observed on the slide that are prone to fall during rainy season and posing threat to road and traffic.	Pyroxnitic rocks	・Talus is visible at the slide toe.	b
Sat_N35_31	Slope failure	a	This is a deep seated multiple rotational landslide. Toe of the slide wthic is close to the road to the road is active due to road cutting		・Main body of the slide is consolidated with shrubs and grass	b
Sat_N35_39	Debris Flow	a	The accumulated poorly sorted debris in the erosion channels are already failed and still prone to slope failure and has continuous flowing water,	Dunite and Amphibolite	・The Debris flow is frequently affecting the road, mainly during the rainy season	b
Sat_N35_45	Slope failure	a	The scarp of the slope failure is clearly visible and still prone to rock failure due to presence of detached, weathered and jointed rocks. Presence of the loose debris in the upstream of slide also cause debris flow during heavy rains.	Dunite	・Loose talus deposits are present on above and below the road.	b
Sat_N35_53	Slope failure	a	Hanging boulder in the debris that pose threats to the road and traffic. The slide is mainly activated during the rainy season and the loose debris can also leads to debris flow		・Tension cracks and open joint are present on the slide. Talus is present on the upper and lower side of the road.	b
Sat_N35_54	Slope failure	a	The exposed bed rock on the left flank of the slide has detached, fractured and jointed boulders that are prone to rock fall and therefore posing threats to the road and traffic		・Talus is present above and below the road.	b
Sat_N35_86	Rockfall	a	An almost vertical rock cliff of hanging boulders. The falling rock can directly hit the road or traffic and therefore posing serious and continuous threats.	Amphibolite	・Rock joints are dipping towards road side	a
Sat_N35_112	Rockfall	a	A steep cliff with jointed, fractured and detached boulders.	Amphibolite	・Houses and hospital is located nearby	b
Sat_N35_115	Slope failure+Rockfall	a	An active slope failure and rock fall. Originally a rock fall, however, talus of 16 m is accumulated at the rock fall toe that is prone to slope failure.		・On the rockfall cliff there are many jointed and detached boulder that poses threats to road and traffic	b
Sat_N35_116	Slope failure	c	It is a historical landslide, which is reactivated many times. Initially it was rockfall but now it is slope failure in debris/talus deposit. Deposit comprises of some boulders of size >6 m3.	Kamila amphibolite	・The site (Chochang) has a history of road blockade	b
Sat_N35_117	Slope Failure	a	Active erosion on the talus leads to development of gullies. Water is flowing through the talus and also seeps in the debris. Hanging boulder are present in the debris. The slide is active during the rainy season and can also leads to a debris flow.		・ It is damaging the road, however, no mitigation measures are adopted to protect the road.	b
Sat_N35_119	Rockfall	a	Uncontrolled blasting for road excavation triggered this site. In addition to it, river is eroding the valley side of the road resulting in over steepening of the slope towards valley side	Kamila amphibolite	・There is retaining wall towards valley side for road protection	b
Sat_N35_134	Slope failure+Rockfall	a	Uncontrolled blasting for road excavation triggered this slope.	Granulite	・Slope is collecting a lot of surface runoff due to large catchment area, further leading into gully erosion	a
Sat_N35_162	Slope failure+Rockfall	a	Slope failure mostly occurs during rainfall when rainwater is infiltrated into deposit	Gabbro	・Gully erosion is prominent in debris/talus	a
Sat_N35_214	Debris Flow	a	Debris consisting boulders sizes ranging 1~2m2 has a potential to fill the road during rainy season	Amphibolite, Gabbro	・No proper drainage control measures has been incorporate	b
Sat_N35_236	Slope failure	a	During rainfall, the talus slope failure makes this site vulnerable. Due to this surface runoff, gully erosion are visible and prone to debris flow.		・Large Talus slope with multiple scarps within the main slope failure.	b
Sat_N35_270	Debris Flow	a	Mouth of channel is very wide near road forming a fan shaped structure containing boulders of different sizes		・Sides of channel are steep having overhangs.	b
Sat_N35_272	Debris Flow	b	The stream contains considerable amount of debris containing some boulders of size 0.5 m3, which can threaten stability of the highway		・Two channels with large catchment area.	c
Sat_N35_286	Rockfall	a	Talus deposit is present in gully and flooded on the road during or after rainfall. Furthermore, the presence of overhangs is increasing vulnerability of the site.	Gabbro	・hree joint sets with average joint spacing 1-2 meters exists leading to wedging failure.	b
Sat_N45_1	Rockfall	a	This cut slope is generated during excavation	Marble and quartzite	・Clayey material is found on both sides of the rock fall	b
Sat_N45_2	Rockfall	a	This cut slope is generated during excavation	Marble		c
Sat_N45_3	Slope failure	a	Few boulders at the top and mid of the slope failure which threaten the road and traffic. This 300 to 400 m wide road section was highly susceptible to erosion.	Boulders, gravels, pebbles and cobbles with sandy, silty clayey matrix		b
Sat_N45_4	Slope failure	a	Gullies are observed at different intervals along the slope failure	Boulders, gravels, pebbles and cobbles with sandy, silty clayey matrix	・About 0.5 to 1m thick sand layers are observed at different levels along the slope ・Road is often blocked during rainy seasons due to material overflow on the road.	b
Sat_N45_5	Slope failure	b	Highly fractured rock along the slope failure	Schist	・4-5 m thick alluvial deposit is also observed along the slope failure	b
N75_1_1	Debris flow+Slope Failure	c	Sub-Himalaya is consisted of Siwalik Group (unconsolidated sedimentary) and vulnerable to the erosion. The slope has became unstable due to weathering and infiltration of rain water into the soil.	Metamorphic rocks of Sub-Himalaya (Sandstone, Mudstone, Shale)	・Debris of the slope failure are found at the bottom of the slope and damaging the gabion on the valley side. Cleaning of the box culvert under the road is advisable.	c
N75_1_2	Debris Flow	c	The debris may flow toward the road during the rainfall.	Metamorphic rocks of Sub-Himalaya (Sandstone, Mudstone, Shale)	・Trace of slope failure damaging the retaining wall beside the box culvert. However, no deposition of debris was confirmed inside the box culvert.	c

No.	Disaster	Disaster Record	Cause	Geology (if any)	Remarks	Hazard
N75_2	Slope Failure	b	Sub-Himalaya is consisted of Siwalik Group (unconsolidated sedimentary) and vulnerable to the erosion. The slope has became unstable due to weathering and infiltration of rain water into the soil.	Metamorphic rocks of Sub-Himalaya (Sandstone, Mudstone, Shale)	・Large slope failure occurred in 2016. Currently, slope countermeasure works (retaining wall, micro piling) is ongoing at the site.	a
N75_3	Debris Flow	c	The debris may flow toward the road during the rainfall.	Metamorphic rocks of Sub-Himalaya (Sandstone, Mudstone, Shale)	・Continuous water flow along the stream ・Several slope failure are confirmed at the east side of the stream.	c
N75_4	Debris Flow	c	The debris may flow toward the road during the rainfall.	Metamorphic rocks of Sub-Himalaya (Sandstone, Mudstone, Shale)	・New trace of slope failure and cracks was confirmed along the stream. ・The slope along this stream is susceptible to the erosion.	c
N75_5	Slope failure+Rockfall	b	Mountain side: rock falls occur constantly because the base rock is highly fractured and weathered. The gabion wall is damaged significantly and doesn't avoid rock fall. Valley side: the concrete retaining wall is tilting because the soil it is constructed on is being washed away.	Metamorphic rocks of Sub-Himalaya (Sandstone, Mudstone, Shale)	・Road subsidence is expected if the slope is not treated properly and protected from further erosion. Superficial slope failure may also occur.	a
Sat_N75_7	Landslide	a	The visible scarp of the landslide indicates this is an old landslide,and has been reactivated many time in the past, consequently, small landslides were also observed within the landslide	Claystone, siltstone and sandstone (Miocene Murree Formation)	・The displacement upto 4 cm has been observed in the retaining wall	c
Sat_N75_9	Debris Flow	a	Big catchment area with debris fall/rock fall material are present on the upstream. Small landslides were also observed along the stream which contribute in the debris volume and have potential to damage the road in future	Sandstone	・During 2007, the debris flow damaged the road completely	b
Sat_N75_20	Debris Flow	a	Due to erosion along two gullies debris material has been found in the river bed. Beside, debris flow, there is also a potential landslide. Large open crack on the top indicates its future potential failure.	Claystone and sandstone	・Small retaining walls has been constructed to protect the road	b
Sat_N75_28	Debris Flow	c	The site is located on a seasonal stream, where road has very sharp bend	Claystone and sandstone	・The culvert has been constructed for the debris outflow	c
Sat_N75_33	Slope failure	a	There are large number of open cracks and hanging boulders	Sandstone and shale	・Landslide was initially triggered during 1992 flood. ・In March 2012, landslide was reactivated during the heavy rainfall	a
Sat_N90_1	Slope failure+Rockfall	a	This is a cut slope mainly triggered due to road construction. Active erosion is present leading to water gullies. Eroded talus is present along the road		・Two roads passes through the slide. Loose debris is present on the slide. It is disrupting the road traffic mainly during the rainy season	b
Sat_N90_2	Slope failure	a	Mainly triggered during the road construction. Detached and hanging boulders are also present.		・The slide is obstructing the traffic mainly during the rainfall.	b
Sat_N90_3	Slope failure+Rockfall	a	Triggered due to construction of the road	Schist and granite	・Retaining wall is built to protect the landslide though no effective counter measures are present.	b
Sat_N90_4	Slope failure	a	Retriggered during the construction of road. Loose debris on the bedrock are prone to sliding		・Shrubs are present on the slide with no trees	b
Sat_N90_5	Debris Flow	a	The debris flow is active mainly during the rainy season blocking the road and obstructing the traffic. A channel is develop to drain the debris flow		・A very active debris flow mainly triggered during the intense monsoon rainfall of 2010 blocking the road for 3 weeks	a
Sat_N95_1	Slope failure	a	Active soil erosion on the slide leads to development of gullies on the slide. Around 15 meter of slide scarp is prone to rock fall that often reach to the road	Boulders, gravels sand and silt	・The slide has the potential to damage the road and disrupt the traffic mainly during the rainy season	b
Sat_N95_2	Debris Flow	a	Source of the DF is steep scrap with detached and jointed boulders. Eroded talus is present	Boulders and gravels	・The slide is mainly triggered during the rainy season. The DF can affect the road and disrupt the traffic	b
Sat_N95_3	Debris Flow	a	Water is coming in the slide from the upstream glaciers. Upstream of the debris flow is also prone to rock fall		No counter measures are constructed to stabilize the slide	b
Sat_N95_4	Slope failure+Rockfall	a	Source of debris is from steep outcrop with fractured and jointed rocks. Hanging and detached boulders are lying on the debris that are prone to sliding during the rainfall	Boulders, gravels, sand and silt	・Excavation of the loose debris for construction material also trigger the slide	b
Sat_N95_5	Debris Flow	a	Detached boulders are lying on the debris that are prone to slide to the road	Boulder, gravels, sand and silt	・Excavation of the loose debris for construction material also trigger the slide	b

<Disaster Record>		
	a	There were obstacles to the road traffic
	b	There is disaster record though there is no obstacle to traffic
	c	No disaster record or there is a disaster which did not get to the road

<Hazard>		
	a	High possibility of disaster
	b	Intermediate possibility of disaster
	c	Low possibility of disaster

4.4 Countermeasures with assistance of donors

4.4.1 Situation of the Road Landslide along the Target Road

The consideration of each target road has been carried out based on the results of the field survey. The road landslide situation of N15, N35, and N75 are as mentioned below.

N15

N15 is a national highway leading to approximately 229 km north from Mansehra (KP Province).

The road is located on the northwest of Himalayan Range, where the steep mountain was formed by the orogenic activities and numerous faults. The geology of this area consisted of metamorphic rocks (Schist, Gneiss, Phylite, etc.) of Lesser Himalaya. Most of the rocks in this area are fractured owing to the fault activity, making the slopes vulnerable to failure from other areas. In addition, the slopes have become more vulnerable during the snow melting season as the level of the surface/groundwater water increases.

As for the road, it is mostly constructed along the steep cut slope, which is prone to slope failures/rockfalls as the slopes have become unstable owing to weathering and erosion. In addition to the slope failures/rockfalls, the road has become prone to the debris flow during snow melting season (March to April) and rainy season (June to September), where the road could be closed for several days.

Figure 4.33 Road Situation of N15

Source: JICA Survey Team

From the results of the field survey, slope failures are a common problem in N15. In particular, the priority is high for the slope failures on N15_3 and N15_6 as the scales of the disasters are massive and may affect the road traffic. The main cause of slope failure is the weathering and erosion by the severe climatic condition on the vulnerable slopes, which is formed by the orogenic activity. The seasonal condition (rainy and snow melting season) may be the triggering factor as the infiltration of the surface water into the soil (slope) and the groundwater rise, causing the slope to be more unstable. In addition, the inadequate construction of the road embankment (selection of the materials, lack of leveling and compaction, inadequate treatment of the cut slope boundary, etc.) is another triggering factor, weakening of the road embankment owing to groundwater rising within the embankment and subsidence of road concrete/asphalt.

Figure 4.34 Slope Failure Affecting Road Traffic at N15 Source: JICA Survey Team

Figure 4.35 Example of Inadequate Angle of Cut Slope and Road Embankment
Source: JICA Survey Team

Boulders (diameter larger than 3 m), which come from the vertical slope at N15_8, were confirmed at the other side of the road (valley side). The isolation of the road is necessary as the site is currently hazardous to road traffic.

As for the N15_9, the existing retaining wall on the valley side has collapsed partially owing to erosion of the base rock (fractured pelitic schist). The retaining wall stands on the slope, where the erosion is caused by attacks from the rapid flow of river water. As a result, the road side and embankment above the existing retaining wall have become unstable (tilting and deviation of the road side).

Figure 4.36 Vertical Slope of (N15_8) and Collapsed Retaining Wall (N15_9)
Source: JICA Survey Team

N35

N35 is a national highway leading to approximately 229 km north from Hasan Abdal (Punjab Province).

The road is located on the northwest of the Himalayan Range and consists of metamorphic rocks of Greater Himalaya.

Surface collapse at N35_1

Rockfall at N35_8

Figure 4.37 Road Situation of N35

Source: JICA Survey Team

N35 (also known as Karakorum Highway) was constructed in 1979 and is the only land route connecting Pakistan and China. Most of the slope failures along the N35 likely occur due to inadequate construction methods (including cut slope angles) during the road construction.

From the results of the field survey, rockfalls are the most common problem on N35. In particular, high priority was given to N35_7 (rockfall) and N35_9 (debris flow), which are the additional requested roads of NHA (Abbottabad Office), as these could affect the road traffic during disaster occurrence. An urgent response is necessary for N35_7 (rockfall), as the fractured was observed on the detached rock on the top of the road.

As for N35_9 (debris flow), a large amount of debris floods the road and blocks the road traffic for several days each rainy season. The amount of debris flooding the road is relatively large in contrast with the gentle angle of the stream bed (less than 15). In addition, the stream width and depth increase each rainy season, which means the large amount of debris is likely supplied from the stream erosion.

Detaching rock on top of the road (N35_7)

Exit of the stream (N35_9)

Figure 4.38 Disaster location along N35 Source: JICA Survey Team

N75

N75 (approximately 75 km) is a road connecting Islamabad and Kohala (Punjab).

This part of the Himalaya Region consists of sedimentary rocks (alternation of sandstone, mudstone, and conglomerate) of Sub-Himalaya geology.

Alternation of sandstone and mudstone

Recovery construction at N75_2

Figure 4.39 Road Situation of N75

Source: JICA Survey Team

Most of the road landslides along the N75 are triggered by the inadequate methods employed (and resulting poor conditions) in the road construction. Countermeasures (predominantly retaining walls) against the road landslides are already in place at the most vulnerable areas along the N75, which is an important route considering the high traffic volume and the presence of various hotels that often host world conferences and tourists. However, most of these countermeasures cannot be considered permanent features.

The materials filling the embankment were found to have deteriorated from the slaking due to the permeation of surface water that had collected in the side ditch, which had been ill managed at almost six slopes along the N75. Slaking is a phenomenon by which soft rock such as mudstone becomes clayey and its strength decreases sharply after its composite becomes particulate because of alternating of dryness and wetness. Especially at slope No. 2, the embankment was observed to have swelled, causing the retaining wall to break despite repeated efforts of reconstruction. A remedial measure, such as inverting concrete, is suggested to be installed on the basement of the side-ditch so as to prevent water permeation to reduce the flow of water into the embankment.

A well-managed drainage plan for the pavement is required to examine its longitudinal and transversal inclination to reduce the weathering effect from the permeation of surface water resulting from rainfall. At slope No. 5, the cracks in the pavement could be suggested as conduits enabling the eventual permeation of surface water into the embankment, which then experiences slaking.

As for the countermeasure works adopted by the NHA as emergency measures after a landslide, micropile structures were implemented to prevent any further sliding of landslide mass onto the road embankment. The dynamic mechanisms of micropile structure coordination differ depending on the rock/soil property of the landslide mass. Any countermeasure involving micropiles must determine its formation mechanism. Thus, a geotechnical survey will be needed to determine to what extent the landslide mass is extended and what type of soil is distributed along the road slope. The slip surface will be determined by boring core sampling and observation/monitoring using an inclinometer. Then, design and construction with proper quality should be implemented to determine the coordination and number of micropiles, such that the micropiles can exert themselves to stop the landmass movement in the slopes along the road.

4.4.2 Typical Road Landslides in Pakistan

Many cases of failure of cut slopes on mountain sides, and embankments on valley sides are found on/along the roads in Pakistan. The main cause of failure of cut slopes on mountain sides is considered to be the unsuitable angle of the cut slope against the geological material of the slope, many examples of which were confirmed. Therefore, the standard for cut slopes in Pakistan shall be improved to contribute to the mitigation of road landslides, and reviewed with the aim of helping road engineers to easily determine a suitable slope angle that can be applied according to the actual geological conditions in Pakistan.

A combination of several factors, including those geological and geotechnical in nature, can be thought of as the natural causes of landslides. The heavy rain associated with these areas (coupled with ill-managed drainage) can be considered enablers or inducers of the aforementioned cause.

In the presence of geological conditions such as a fault like the MBT, fractured rock caused by weathering, along with a high level of groundwater, advances the process of landslide initiation. Moreover, geotechnical factors affect the destabilization of the slopes.

The main causes of the failure on embankments on valley sides from the perspective of geological and geotechnical factors, are considered to be the following: 1) poor quality of embankment (e.g., inadequacy of compaction and unsuitability of the mechanism for the control of moisture build-up); 2) lack of bearing capacity of footing on an embankment; and 3) no/inadequate drainage system for an embankment. Investigation, design, and construction supervision must be carried out properly to avoid these causal factors to reduce the frequency of road landslides.

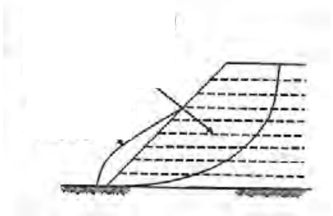
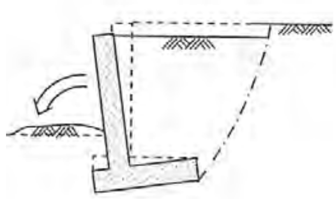
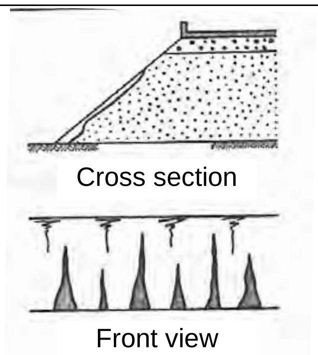
		
Slope failure due to inadequate compaction, and unsuitable control of moisture contents	Lack of bearing capacity of footing on embankment	Surface erosion due to no/inadequate drainage system

Figure 4.40 Examples of Inadequate Road Embankment

Source: Japan Road Association[46][47]

[46] Specifications for Embankment (Japan Road Associations, 2010)
[47] Specifications for Retaining Wall (Japan Road Associations, 2012)

Figure 4.41 Inadequate Cut Slope Angle (Left) and Lack of Bearing Capacity of Embankment (Right)

Source: JICA Survey Team

The slope situation of the left photograph of Figure 4.41 needs a re-profiling of the slope by bench cutting and shotcrete for rockfall protection. For the concrete pavement on the right photograph of Figure 4.41, surface water is intruding from the space created between the joint of concrete pavement, causing the weakening of and tilting of the concrete pavement toward the valley side.

4.5 Analysis and Issues of Road Landslide Countermeasures

4.5.1 Standard Countermeasures for Road Landslides

There are many structural countermeasures for road landslides, and the countermeasures are selected based on disaster type and volume, technical difficulty, and element availability. In this project, the standard countermeasure works for road landslides are defined in consideration of feasibility and sustainability in Pakistan and are applied as the proposed countermeasure works for the future. Even though countermeasure works are proposed in the first stage, the countermeasure works may change at the actual design stage according to the results of further investigation and analysis.

The features of countermeasure works are compiled in a list, including the name, purpose, and availability by each disaster type, yielding a catalog of the standard countermeasure works. The list is referred to in the Appendix 3 of the report.

Table 4.22 Selected Standard Countermeasure Works Source: JICA Survey Team

Type			Name	Purpose
Landslide	First, control works, and then prevention works. Control works are the countermeasure works that reduce the cause of landslides. Prevention Works are the countermeasure works that utilize artificial structure to prevent the movement of the slope.	Control Works	Surface Drainage (Open Ditch)	Drain surface water
			Open-Blind Ditch (French Drain)	Drain surface water and ground water
			Horizontal Drainage	Drain ground water
			Drainage Well	Drain ground water
			Drainage Tunnel	Drain ground water
			Earth Removal	Reduce sliding force
			Counterweight Fill	Increase resisting force
		Prevention Works	Steel Pile Work	Increase resisting force
			Cast-in place concrete Shaft (Caisson)	Increase resisting force
			Ground Anchor	Increase resisting force
Slope failure (mainly soil)	Based on the situation of a soil slope, the countermeasure works are either prevention or protection works. Preventions works are to reduce the risks before slope failures, and protection works are to protect neighboring infrastructure in case of slope failures.	Prevention	Surface Drainage	Drain surface water
			Bio engineering (Re-vegetation)	Retain slopes stability and protect erosion
			Wicker Fence	Retain slopes stability and protect erosion
			Wooden Log Crib	Retain slopes stability and protect erosion
			Stone Pitching	Retain slopes stability and protect erosion
			Retaining Wall	Retain slopes stability
			Barrier Wall	Protect road from collapsed soil
			Re-shaping slope with Benching	Fix unstable slopes
			Concrete Crib	Fix slopes and protect from weathering
			Shotcrete	Protect slopes from weathering
			Ground Anchor	Fix unstable slopes and rocks
		Protection	Soil Catch Wall	Prevent slope soil to reach roads
Slope failure (mainly	Based on the situation of the rock slope, the countermeasure works	Prevention	Rock Removal	Remove unstable rocks
			Retaining Wall	Stabilize unstable rock mass

Type			Name	Purpose
rock)	are either prevention or protection works. Preventions works are to reduce the risks before slope failures, protection works are to protect neighboring infrastructure in case of slope failures.		Barrier Wall	Protect road from fallen rocks
			Protection Rock Net	Protect road from fallen rocks
		Protection	Rock Bolt (Nailing)/Anchor	Fix unstable rocks
			Fixing Work by shotcrete	Fix unstable rocks
			Rock Catch Net	Fix unstable rocks
			Rock Shed Work	Protect road from fallen rocks
Debris flow	Construct a dam in the upstream to reduce debris, or construct a wall along a road to protect damage by debris		Sabo Dam	Catch debris and soil, and break energy
			Check Dam	Catch debris and soil, and break energy
			French Cascade	Break energy
			Culvert	Discharge debris and water without influence on road
			Buffer Forest	Catch debris and soil, and break energy
			Shed Work	Discharge debris and water without influence on road

4.5.2 Road Landslide Countermeasure on the Target Roads

The issues of the road landslide countermeasures observed on the field survey are as described below.

Retaining wall (dry masonry, mortar masonry, leaning type, gravity type, etc.), ditch, and drainage, which are likely to be constructed by the local contractors (excluding the countermeasures works carried out by CPEC), are the common countermeasures for the mountain side on the target roads. Moreover, retaining wall (dry masonry, mortar masonry, leaning type), gabion, vegetation mat (local plants are planted in grid within bamboo knitted sheet) and micropiling (piling combined by H steel) are the common countermeasures for the valley side on the target roads.

Figure 4.42 Masonry on the Valley side of N75 Source: JICA Survey Team


Figure 4.43 Surface Drainage on the Valley side (Left) and Box Culvert Crossing the Road (Right): Both functions are to Reduce Flow Speed Source: JICA Survey Team

As for the treatment of the road surface (pavement), rigid roadbed (concrete pavement) is combined with asphalt pavement and reinforcement used within the concrete pavement does have enough thickness and density. The concrete pavement is used instead of box culvert, particularly at the road near the stream exit to endure the force of glacier melting. Concrete pavement is stronger than normal pavement and constructed with the lower gradient toward the valley side to invert the glacier on the road (taking adaptive measure at present).


Figure 4.44 Examples of Concrete Pavement (N15_8) and Inverted Pavement to Minimize the Impact of Glacier (N15_10) Source: JICA Survey Team

The analysis of road landslide countermeasures by the local contractors are as described below.

1) Investigation: Local contractors do not perform the ground survey systematically to consider the characteristics of the landslides (mechanism, necessity of countermeasure, etc.). In Japan, various methods (field survey, soil sampling from boring survey, monitoring by tiltmeter) are applied and the identification of the boundary (slip surface), unstable landmass (cause of the landslide) and base rocks, are determined comprehensively by the engineer. However, in Pakistan, the actual implementation of the countermeasure work, and the slope surface are also judged by the geotechnical consultant utilizing empirical methods, such as electrical prospecting and ground-penetrating radar. Ground-penetrating radar projects electromagnetic into the subsurface, which

detects reflected signal (difference of dielectric constant) from the subsurface structure (soil, sand, bedrock, cavity, waste). The depth of each subsurface structure can be estimated by this method. Electrical prospecting captures the electric potential distribution from the specific electrical resistance difference of the subsurface structure (stratum (sediment), groundwater, bedrock, etc.). The survey by ground-penetrating radar is highly reliant on the ability of the engineer as the survey results sometimes may not show the true value owing to influence of water content of the subsurface (existence of groundwater), cracks, and the pseudo reflection layer created by the data processing. In addition, the maximum survey depth of the ground penetrating radar is 2 m[48], which is too shallow to search the slope surface (often used to survey the pipes beneath the road and cavities within a river embankment). As for electrical prospecting, there is also a technical difficulty in reading the slope surface, because the result may vary depending on groundwater level (high during rainy season or monsoon and low during dry season).
Owing to the technical difficulties mentioned above, there is high possibility in which the accurate slope surface could not be captured during the ground survey before the implementation of countermeasure work. The worst case assumed is where the micropile did not penetrate the slope surface because the depth of the slope surface from the ground survey result was shallower than the actual depth. As a result, the insertion of the micropile ended before reaching the slope surface and could not prevent the slope failures.

Figure 4.45 Insertion of Micropile (Left) and Failure of embankment in the valley side (Left)
Source: JICA Survey Team, November 2017

48 http://rooten.jp/tvtop.html#G1

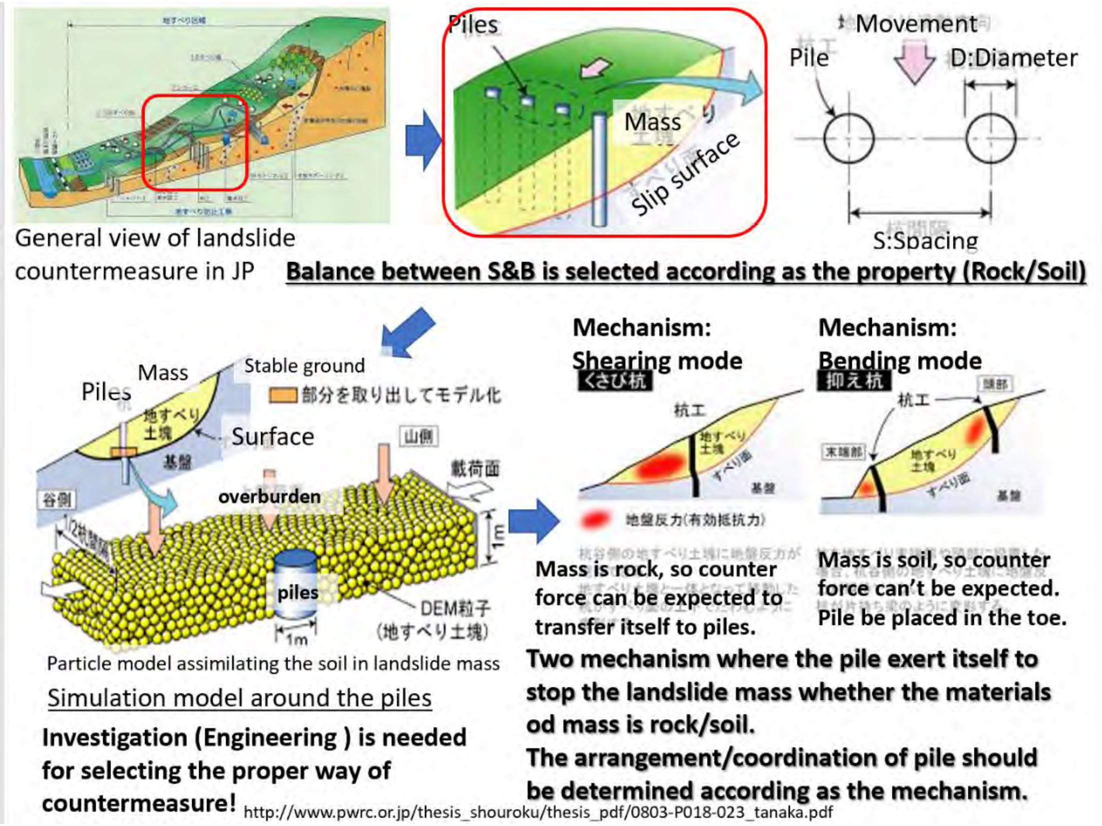


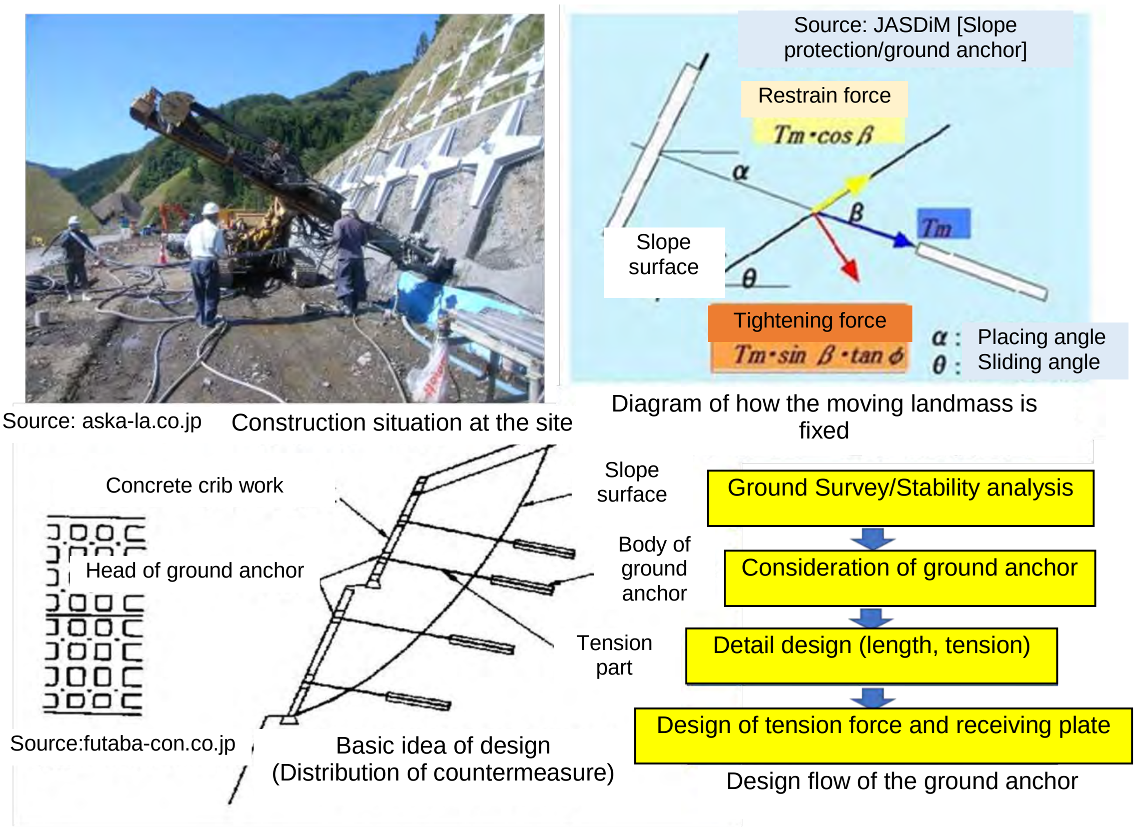
Figure 4.46 Dynamic mechanism of the piles in the landslide mass and simulation models how the piles function to restrain the landslide

Source: compiled by JICA Survey Team, November 2018, Report from Public Works Research Institute in Japan

The actual slope surface can be confirmed mostly through the proper boring survey as the surrounding of the slope surface is usually fractured by to the shearing between the bedrock and moving landmass. With this procedure, a more accurate depth of the slope surface can be collected, which can improve the design of the countermeasure and lead to higher quality and long-lasting countermeasure work)[49].

2) Design: There is tendency of mistaking the area for the countermeasure work (qualitative) and inadequate input of budget to stabilize the road landslides considering the economic efficiency of the road (quantitative). Specifically, on the qualitative aspect, the length of prevention pile could be insufficient owing to the incorrect depth setting of the slope surface. This would then lead to the judgment of the necessary depth to stabilize the slope failure during the actual construction (would affect the quality of the construction). As for the quantitative aspect, the necessary input of the resource (construction materials) is determined usually based on the index of slope stabilization (safety factor) set considering the priority of the conservation target. However, the application of this engineering approach is rather low in Pakistan, as it relies more on the experience of the subcontractor.

[49] Guideline of River Works, Investigation volume (MLIT)



Source: aska-la.co.jp Construction situation at the site

Diagram of how the moving landmass is fixed

Source:futaba-con.co.jp Basic idea of design (Distribution of countermeasure)

Design flow of the ground anchor

Figure 4.47 Basic Flow and Diagram of Ground Anchor Source: JICA Survey Team

For example, in the case of ground anchoring depicted in Figure 4.47, the stability is analyzed based on many factors such as soil cohesion, internal angle of friction, coefficient of friction along the slip surface, angles of sliding (slip surface) and placing (ground anchoring), and the mechanical strength of PC cables assembled using steel wires. The design factors are tested, and calculations are performed as a proof of on-site construction based on a pulling test at each site when using jacking.

Many slope failures are found on artificial cut slopes on the site. As mentioned above, the cause of the failures on cut slopes is unsuitable angle of the slope against geological material. Therefore, the standard of the cut slope in Pakistan should be improved to contribute to the mitigation of road landslides and be reviewed with the aim of helping road engineers to easily determine a suitable slope angle that can be applied according to the actual geological conditions in Pakistan.

In most cases, the cost of countermeasures executed after disasters is much higher than pre-countermeasures on disaster-prone areas in the construction stages, because the target area becomes wider and the condition becomes more severe. Therefore, appropriate investigation, design, and supervision based on the results of the investigation are required in addition to revising the standard for cut slopes. Those appropriate works will contribute to mitigating road landslides in Pakistan.

<u>3) Construction materials of countermeasure work</u>: It is preferable to deploy the countermeasure plan based on the proper design considering the characteristics of the material (size and availability) and mechanical strength (shape retention performance against compression/tensile/shear and water). From the observations of countermeasure works by the NHA, the construction materials such as sand, crushed rock, concrete, reinforcing bar, and wood pile are commonly used. It seems that there are no problems with the availability of these materials. However, there were no cases where PC steel wires, pressure plates, secondary fabricated construction materials (i.e., anchor, rocknet, etc.) were used in the road landslide countermeasure works.

Additionally, the engineering approaches (strength calculation of construction materials from the results of external force analysis of slope surface) to determine the distribution and quantity of construction materials were not observed.

<u>4) Construction quality</u>: It seems that there was no effort given in NHA to secure the quality of the construction, such as combining materials to produce proper strength of countermeasure, proper handling of materials, foundation work, removal of surface soil (pre-treatment work), disposition of surface water (which will cause deterioration of pavement materials) and others. The specific points are described below.

- As for the proper handling of materials, the embankment materials are packed into a cement bag and then filled as part of the embankment (embankment fill on valley side of N75). The structure of the embankment does not consider the distribution particle size of soil materials (soil, sand, etc.). Additionally, the criteria of the compaction strength of embankment according to the particle size does exist in the road construction technology in other countries.


Figure 4.48 Inadequate Construction of Embankment on the Valley side Slope at N75
Source: JICA Survey Team

- As for foundation work, usually, the removal of the surface vegetation and weathered bedrock is conducted before the foundation work (spreading of crushed stones to minimize the ground pressure of the retaining wall resting on it) to fix the retaining wall on the proper foundation. However, from the observation of one of the construction sites by the NHA (N75_5), weeds from the cracks were confirmed on the existing retaining wall. This means that the foundation work and removal of vegetation/soil was insufficient, which was the reason for the retaining wall collapse and road embankment instability.

Figure 4.49 Inadequate Construction of Retaining Wall on the Valley side Slope at N75_5

Source: JICA Survey Team

- As for disposition of surface water, cracks were observed at the side and bottom of the ditch, which was supposed to channel the water from the mountain side to the valley side (N75_2). Additionally, the construction of the ditch did not consider the water gradient (2–3°). This causes the surface water to infiltrate the road embankment, which was the reason for the surface collapse of the road embankment.

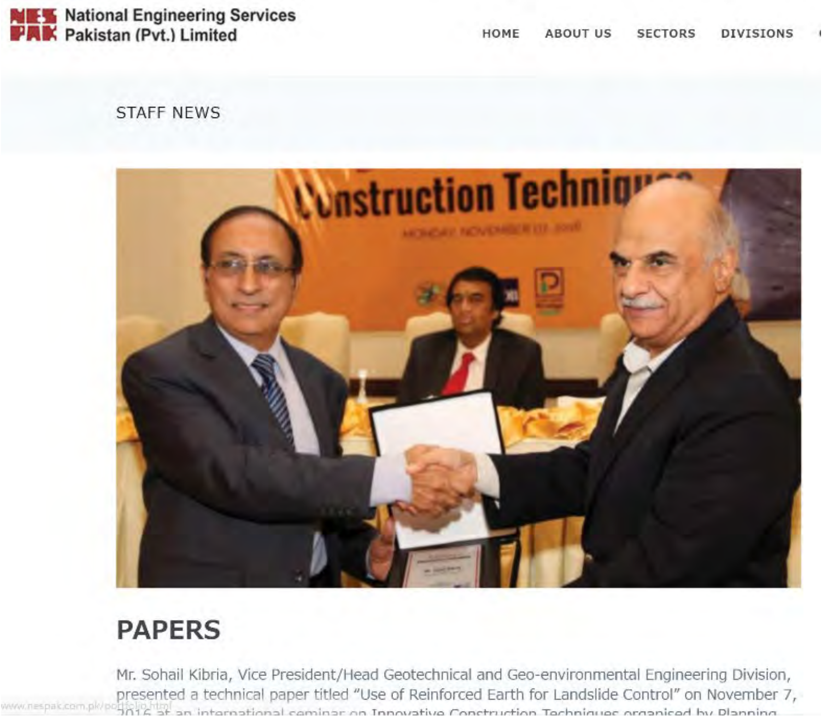
Figure 4.50 Puddle in the Ditch (Left), Situation of the Surface Drainage (Right) at N75_2

Source: JICA Survey Team

<u>5) Permanent countermeasure for the slope stabilization</u>: The NHA has been concerned about their countermeasure works, which often ended up damaged after disasters. For this reason, the countermeasure had to be reconstructed repeatedly after each disaster. Insufficient investigation (understanding the conditions, factors, and mechanisms) of the road landslides is the main cause of the problem above. This leads to inadequate design and re-construction, which causes a negative cycle of road landslide countermeasures.

<u>6) Approach of local companies</u>: NESPAK has received an award from the Government of Punjab for introducing a new method (reinforced earth) for the road landslide countermeasure works at Punjab in 2016[50]. This demonstrates that the local companies are eager to introduce new technologies.

[50] NESPAK Webpage, NEWS (http://www.nespak.com.pk/Staff-News.html)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STAFF NEWS

PAPERS

Mr. Sohail Kibria, Vice President/Head Geotechnical and Geo-environmental Engineering Division, presented a technical paper titled "Use of Reinforced Earth for Landslide Control" on November 7, 2016 at an international seminar on Innovative Construction Techniques organized by Planning

Figure 4.51 Article of NESPAK receiving an Award from Government of Punjab
Source: NESPAK Webpage, November 2016

The road landslide countermeasure works carried out on CPEC (particularly along N35) include large-scale slope cutting, crib works, shotcrete, and others. At one of the construction sites managed by China Communication Construction Company Ltd. (CCCC) (CPEC, N35, Havelian section), the re-profiling of the cut slope was being conducted from the upper part, which was then followed by the crib works from the bottom of slope (normal lining method). This method can lead to the possibility of slope failure during the construction if the slope angle is steep, if there is a large/long slope, or if there is an unstable slope (remains of slope failure). Therefore, this slope stabilization method is limited in its applicability. Specifically, the application of this method is difficult at the slopes observed in N15, which are relatively large (length: more than 100 m, height more than 20 m), with much deposition of unstable soil (colluvium).

Figure 4.52 Situation of Slope Stabilization along N35 by Chinese Company (Between Havelian and Abbotabad) Source: JICA Survey Team

The inverted lining method (the series of work is undertaken stepwise when it has reached a certain height to avoid the slope failure) considers the safety of construction as the period of the cut slope being exposed is shorter than the other method and thus is recommended. Moreover, it can be applied at a steep angle slope and is environmentally friendly (less area of vegetation removal). Furthermore, the reason that the Chinese companies are employing the method of cutting slope from the bottom to top can be thought to be why the Chinese companies are now on course of technical developing, and thus they may have some limitations in the technology of slope excavating.


Han Expressway Project


Xi'an-Hefei Expressway


Erlangshan Tunnel of Sichuang-Tibet Expressway

Figure 4.53 Situation of Road Landslide Countermeasure undertaken by China Communication Construction Company Ltd. Source: CCCC Webpage

4.5.3 Issues on Countermeasures Works for Road Landslide in Pakistan

Countermeasure works are found on many slopes along the roads in Pakistan. In many cases, the countermeasure works are applied to stabilize a slope, which is made by excavation work on the mountain side and earth fill work on the valley side, to secure the road width at construction stage of new roads.

Simple earth works, such as excavation and filling and retaining walls, do not require complicated technical knowledge, and are available in Pakistan. In addition, the works that require specific materials and higher techniques, such as ground anchor or steel piling work, are also implemented by local contractors. The works are selected based on the discussion between the NHA and local consultants/contractors at the planning/design stages.

a. Small-scale countermeasure works for road landslides

Countermeasure works, which were conducted on relatively small-scale slope failures, are mainly excavation works to stabilize slopes, and gabion/masonry retaining wall at the toe part of slopes. The countermeasures with sufficient alignment and specification are expected to be effective against road landslides even with such simple works. However, the alignment and specification of several works are insufficient owing to a lack of understanding of the disaster type/volume/place, and thus they are unable to control/restrain disasters effectively. Examples of these are described below.

Table 4.23 Observations and Analysis at each slopes

Slopes	N15_8	N15_9	N35_7	N75_2	N75_2
Situation	High vertical slope	Retaining wall collapses partially due to the river erosion of the bedrock.	Some cracks are developing and detaching on the slope and risk of rockfall.	Inappropriate material choices made when embanking the roads.	Unstable retaining wall on the valley side

Risk	A risk of rockfall to the road user (Car and pedestrians)	The collapse of the retaining wall makes Embankment on the road unstable and easier to collapse.	Rockfall is easy to occur due to the fractures. The rock fall might hit to the car.	Collapse of the road embankment and its traffic disruption are feared.	Inappropriate topsoil stripping detaches to the valley bottom and partially to houses
Policy of Counter measure	Isolation from the hazard (rockfall)	Erosion and prevention work against the water flow of the river.	Covering the slope where the cracks occur by using nets to prevent the rockfall.	Quality of road construction (subgrade and basecourse etc.) should be maintained.	In this case, foundation work, topsoil stripping work and benching work in design and construction phases would be appropriate
Countermeasure	Rockfall prevention work (directly constructing the prevention work at the cliff to prevent the rockfall) will be effective to secure the safety of the road traffic	Foundation work on the riverbank is also necessary to stabilize the installment.	Covering the slope where the cracks occur by using nets to prevent the rockfall or to remove the unstable rock overhanging by blasting them is needed.	Planning of a Rainfall Drainage System on the road, improving construction management of side ditch, and constructing culvert to make the rainwater to be entered the river will be efficient and help prevent future disasters.	Geotechnical investigation should capture the soil property. Stability analysis should be implemented following the results from geotechnical investigation. Appropriate coordination of construction materials should be secured on site (Construction Management).
Consideration		The water levels of the river changes	Static crushing agent or traffic		Stability analysis should be implemented

		seasonally. As it gets higher during the snow melting season, shore protection work is more necessary.	restriction to mitigate the influence on road users are of high importance.		based on the three aspect such as tilting, sliding and subsidence. Construction materials consisting of the retaining wall should be followed based on the results from the stability analysis.

Based on the issues described above, the design and construction of road landslide countermeasures in Pakistan are carried out without proper understanding of the road landslides. Therefore, it is important to properly design the countermeasure works based on detailed site investigations to grasp the type, volume, and mechanism of the target disaster. Additionally, the maintenance of countermeasure facilities should be carried out properly to secure the quality and efficacy of the elements as well as appropriate supervision of the construction stages.

The countermeasure works mentioned above are applied to slope failures, rock falls, and embankment failures. However, there are not many cases applied to the respective countermeasure works for landslides and debris flows.

For a landslide, large-volume, pre-countermeasures before the movement starts are critical because of its costs and the tremendous amount of time it takes once the movement starts. Detailed investigation and monitoring are carried out to grasp the mechanism and volume of targeted landslide for pre-countermeasures.

For a debris flow, most cases are insufficient drainage system for surface water and materials. A culvert or bridge under the road are mainly applied as countermeasure works for debris flow to enable debris discharge safely through those facilities. Expanding the dimension of an existing culvert or the installation of an additional culvert are needed for many cases of debris flow to secure sufficient drainage. Because these works are not difficult and do not require a high cost, it is recommended that debris flow is set as a higher priority to apply countermeasure works.

b. Large-scale countermeasure works for road landslides

Ground anchor works, pile works, large-scale earth works, and/or high retaining walls, etc. are estimated as countermeasures for large-scale slopes. These types of countermeasure works may be difficult to implement in Pakistan from the viewpoint of cost, technical level, and environment/social consideration. Moreover, the temporary works to implement the large-scale works also require substantial costs, because the slopes at high risk are enormous with unstable conditions. Therefore, the methods of implementing temporary works should be discussed beforehand. A tunnel or a bridge is considered as an alternative work to avoid critical hazards to road sections for the large-scale slopes to avoid substantial costs.

Based on the issues described above, the directions of the countermeasure work are described below.

- **Issues of the road surrounding (pavement surrounding)**: Surface water measure of ditch (water gradient), water resistant of pavement (drainage pavement), and drainage system measure of pavement materials.

- **Issues of the countermeasure of the mountain side**: Consistent quality of the road structure countermeasure throughout the survey, design (stability analysis and materials for countermeasure works), and construction; introduction of the prevention work (idea on introducing iron based artificial materials to suppress the moving landmass). Specifically, ground anchor and reinforced earth work.

- **Issues of the countermeasure of the valley side**: Insufficient horizontal distance between the river and road (steep and narrow condition) can be observed at some parts of the slope. In such cases, geotextile or EPS can be used to reinforce and reduce the load of the embankment, prevention of the river bank erosion, installation of steep angle retaining wall (or terre armee) and reinforcement of the embankment at the narrow area (reinforced earth work) are the issues. In addition, it is preferable to install the horizontal boring drainage, as the drainage system within the embankment is also one of the issues.

- **Issues of the construction**: As mentioned in the issues of the road surrounding, the quality of the road construction is the issue to be improved. Specifically, surface treatment, management of the embankment materials (particles management) and compaction (compaction test, uniform the size), drainage of the roadbed (installation of the horizontal drainage), measures against surface water infiltration (conversion to drainage pavement), setting of road surface gradient, management of the water flow inside the ditch, and strengthening of ditch wall (installation of reinforcement and securing the plate thickness).

4.5.4 Comparison of Permanent and Emergency Countermeasures

This section reviews the permanent and emergency countermeasures cost and reliability loss, and life cycle cost with the aim to conduct appropriate evaluations of landside countermeasures. The latter part of this section introduces a comparison example of maintenance cost before and after the implementation/application of a permanent countermeasure in another country.

a. Primary damages by landslide disasters

The loss caused by primary damages by landslide disasters are mainly divided into direct loss and indirect loss, as shown in Figure 4.54.

Direct loss is divided into three categories:

- Personal Loss: Loss of lives caused by landslide disasters.

- Restoration Loss: Loss of road reopening cost required to secure the road function.

- Reconstruction Loss：Loss of design and construction cost, after the restoration, required to secure the road function.

Indirect loss is divided in two categories:

- Detour Loss due to suspension of traffic: Loss of cost generated from traffic detour distance and time consumption during restoration.

- Emergency Medical Fatal Care Loss: Loss of human lives who could not reach the hospital in time to be attended properly due to detours during reconstruction.

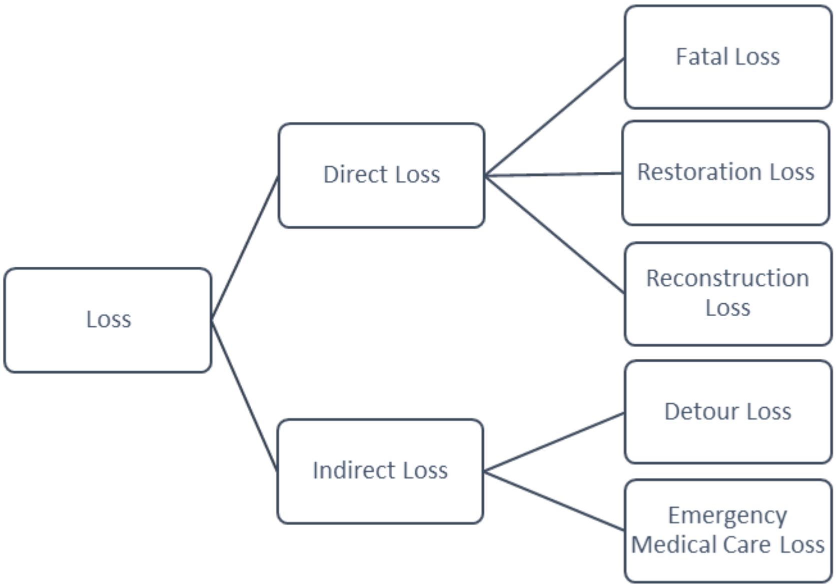


Figure 4.54 Primary Damage Cost Caused by Landslide Disaster

Source: Public Works Research Institute 2014 February

Therefore, once a landslide disaster occurs, the loss of primary damage cost is enormous. Moreover, the loss of social trust of the road management authority due to accidents caused by landslide disasters, the cost of which is difficult to measure, and fatal loss is the most precious value, are more significant than the primary damaged loss cost.

Thus, to avoid the loss of enormous costs caused by repeated landslide disasters, the implementation of appropriate permanent countermeasures is inevitable.

b. Secondary damages by landslide disasters

The previous section explained the primary damages by landslide disasters, which are related to the road restoration and reconstruction. This section explains the loss of secondary damages at the river downstream, which are caused after the primary damage at the upstream.

Many places where river flows adjacent to a road were observed in the survey area. If landslide disasters occur at these places, it may lead to a massive scale of secondary damages at the downstream. The process of the secondary damage occurrence is as shown below.

Landslide failures suspend the river flow, the upstream mud flow forms a sediment deposition at the downstream, and the mud flow deposition collapses. Then, the downstream communities suffer mudflow impacts causing massive economic and social loss. An image of the secondary damages is shown in Figure 4.55. The secondary damage losses are much larger than the primary damages loss in general.

Figure 4.55 Image of Secondary Damages

Source: Sediment Disaster Prevention Publicity Center

The secondary damages occur in the downstream area causing loss of lives and social infrastructure, and damages to communities, agricultural/forestry productive fields, etc.

The period to restore the communities from the second damages takes many years. Moreover, damages related to victims' mental stress and compensation are much larger than the primary loss. The secondary damage loss categories are shown in Figure 4.56.

Therefore, permanent countermeasures should be implemented at roads adjacent to a river flow in consideration of secondary damage losses.

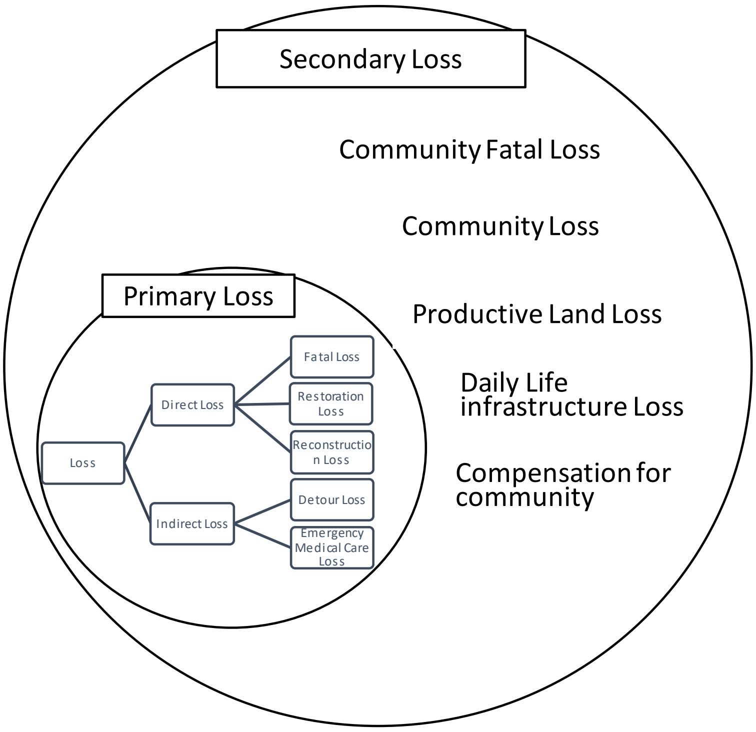


Figure 4.56 Secondary Damage Costs Caused by Landslide Disasters

Source: JICA Survey Team

c. Comparison of Life Cycle Cost between Permanent and Emergency Countermeasures

There were many cases where emergency responses were applied after landslide disaster occurrences; however, after several years, the emergency responses were completely damaged or did not function properly and thus most of these cases have been forced to adopt additional countermeasures. This is because countermeasures are not applied in consideration of long-term resistance against landslide disasters. Therefore, repeated landslide disasters occur, causing the need for additional countermeasures, which may lead to a cycle of negativity by continuing applying them.

The future expenditure of the maintenance can be minimized by maximizing the initial investment on the proper countermeasure works. However, there is also a case where the initial investment of the countermeasure works is minimized and the additional countermeasure works is planned and added during the emergency if necessary. Additionally, there is a case of repeating the maintenance and reinforcement at the small sites and also undertaking a limited amount of maintenance and reinforcement at the larger sites. The appropriate life cycle cost can be obtained by calculating the life cycle cost of each cases.

Images of the comparison of permanent and emergency countermeasure life cycle costs are shown in Figure 4.57 and Figure 4.58. The pre-condition of both figures assumed that the permanent countermeasure total life cycle cost is lower than the emergency cost over several decades.

c.1 Case Study: Comparison of Permanent Countermeasures and Emergency Countermeasures without proper maintenance and when these reach to their application limit and reconstruction will apply.

In Figure 4.57, the left vertical axial stands for soundness of facilities, the horizontal line stands for time, the red line stands for permanent countermeasures, the blue line stands for emergency countermeasures, the solid line stands for cost, and the dotted line stands for soundness of facilities. Application limit stands for the limit strength of facilities.

As mentioned in Chapter 2.5, several countermeasure works were undertaken after a large disaster in 2009 (Figure 2.8) and 2015 (Figure 2.9) in N-75. The budget expenditure for the countermeasure at from 2014 to 2016 at these three sites was approximately Rs. 300 million. Although, the budget expenditure for the countermeasure works in 2009 is unknown, the total expenditure for the emergency countermeasure works at this site is likely to be approximately Rs. 600 million (estimating the same expenditure as 2014 to 2016 based on the drawings of Figure 2.8).

The following can be assumed when installing the permanent countermeasures (permanent countermeasure cost is four times (Rs. 2,400 million) the emergency countermeasure cost).

- Emergency countermeasure cost is 100 in 2018, and its permanent countermeasure cost is 400.

In addition to the above, the following were assumed from the past example of the emergency countermeasures in general.

- Periodic maintenance of emergency countermeasures is carried out by the yearly regular maintenance cost of 10% of the initial construction cost. Rehabilitation of permanent countermeasures is applied after 15 years of the initial construction by 25% of the initial construction cost.
- Emergency countermeasures reach their application limit in 10 years and these collapse completely, soon after which reconstruction of emergency countermeasures is implemented.

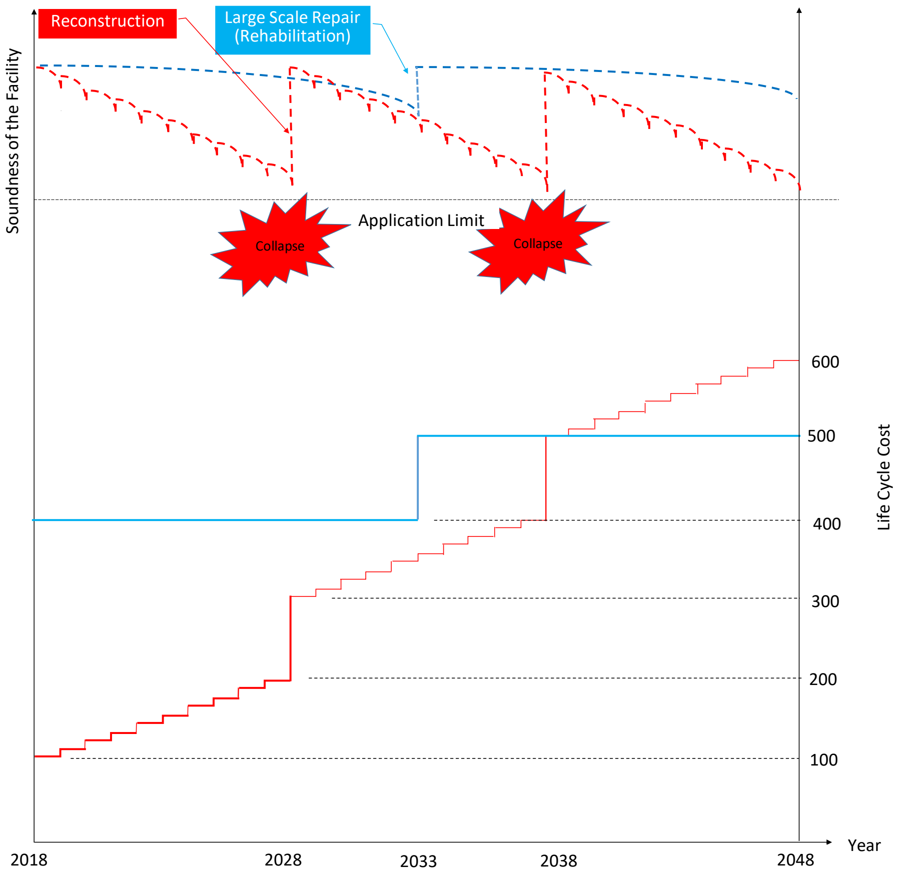


Figure 4.57 Life Cycle Cost of Permanent Countermeasures and Emergency Countermeasures in the Case of Reconstruction of those that Reached Their Application Limit

Source: JICA Survey Team

Based on the assumptions above, the life cycle cost of emergency countermeasures in 2048 will be 600, and for the permanent countermeasures will be 500. The life cycle cost of both countermeasures will diverge and increase after 2038.

Therefore, permanent countermeasures shall be prioritized based on this assumption of life cycle cost for more than 20 years after installing countermeasures.

The abovementioned simulation of emergency and permanent countermeasures may be different depending on each countermeasure vulnerability/solidity assumption.

c.2 Case Study: Comparison between Permanent and Emergency Countermeasure Life Cycle Cost under Proper Maintenance

The previous section explains that emergency countermeasures cannot function properly and collapse completely after 10 years of the initial construction without proper maintenance, as well as the implementation of emergency countermeasure reconstruction. This section explains the comparison carried out in case where a 5-year interval of proper periodic maintenance is applied for the emergency countermeasures and the rehabilitation after 25 years of the initial construction is applied to the permanent countermeasures.

In Figure 4.58, the left vertical axial stands for the soundness of facilities, and the horizontal line stands for time.

The following are the assumptions:

- Emergency countermeasure initial cost is 100 in 2018, and its permanent countermeasure initial cost is 150. The pre-condition is assumed that the permanent countermeasure total life cycle cost is lower than the emergency cost over several decades, with the following two assumptions: the emergency countermeasure cost and permanent countermeasure cost is assumed 100:150.
- Every five years, periodic maintenance is carried out and its cost is 10% of emergency countermeasure initial cost. The rehabilitation is applied for both emergency countermeasures and permanent countermeasures with 30% of the initial cost.
- Rehabilitation of emergency countermeasures is applied when these reach 25 years, which is the application limit. Additionally, the rehabilitation of permanent countermeasures is applied when they reach 40 years.

Based on the assumptions above, the life cycle cost of emergency countermeasure maintenance is 200, and that for the permanent countermeasures is 195. The life cycle cost of both countermeasures will diverge and expand after 2058.

Even if the proper periodic maintenance and rehabilitation are applied under the above assumptions, the emergency countermeasure soundness will not be equal to its initial strength, and it will deteriorate year by year and ultimately reach its application limit.

In the case that the proper rehabilitation is applied to permanent countermeasures, the soundness of facilities of these will be recovered as equal to the initial strength, and it will be able to continue functioning after 2058. Thus, the life cycle cost of permanent countermeasures shall be prioritized rather than the life cycle cost of emergency countermeasures after 2058.

The abovementioned simulation between emergency and permanent countermeasures may be different, depending on the countermeasure vulnerability/solidity assumptions.

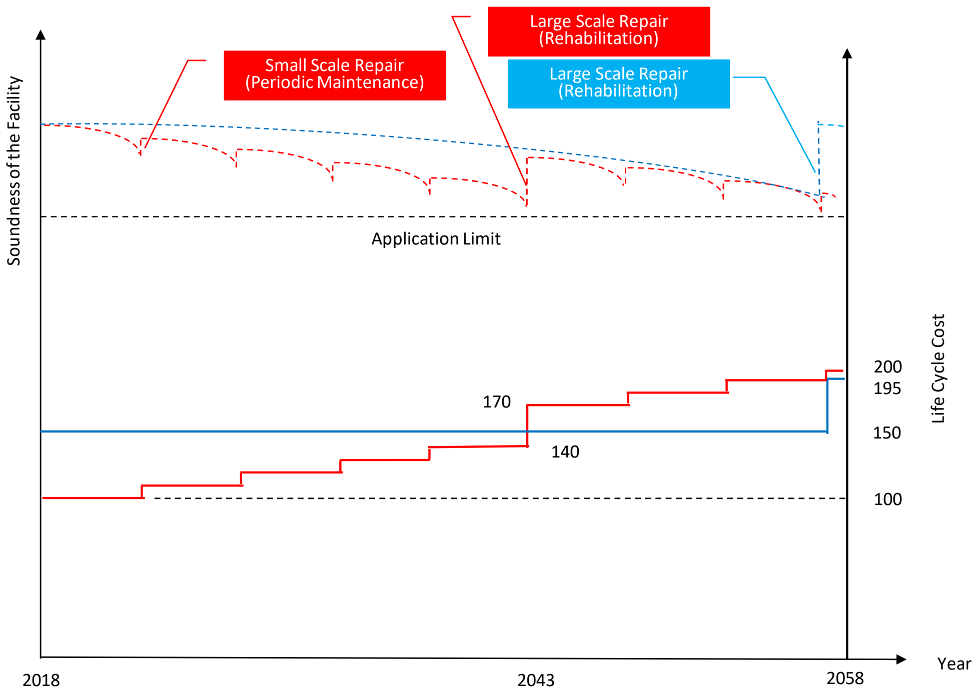


Figure 4.58 Life Cycle Cost of Permanent Countermeasures and Emergency Countermeasures under Proper Maintenance Source: JICA Survey Team

d. Example of Maintenance Cost Reduction for Permanent Countermeasures

The government of Japan provided a grant aid project on coastal protection by permanent countermeasures at Male Island, Maldives, in 1994, as shown inFigure 4.59 Figure 4.59. After the completion of the permanent countermeasures, the coastal protection maintenance cost was drastically reduced from 30% to 1–2% of the total budget[51], as shown Figure 4.60.

This example shows that the application of permanent countermeasures reduces the life cycle cost in the long term compared to the emergency countermeasures.

Figure 4.59 Permanent Coastal Protection provided by Japan's Grant Aid

Source: Ministry of Foreign Affairs, Japan Webpage

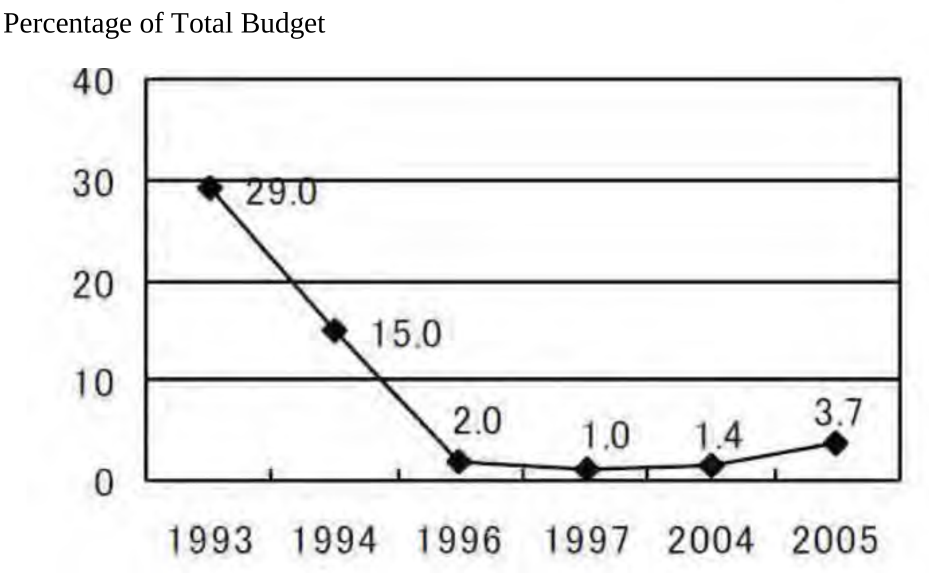


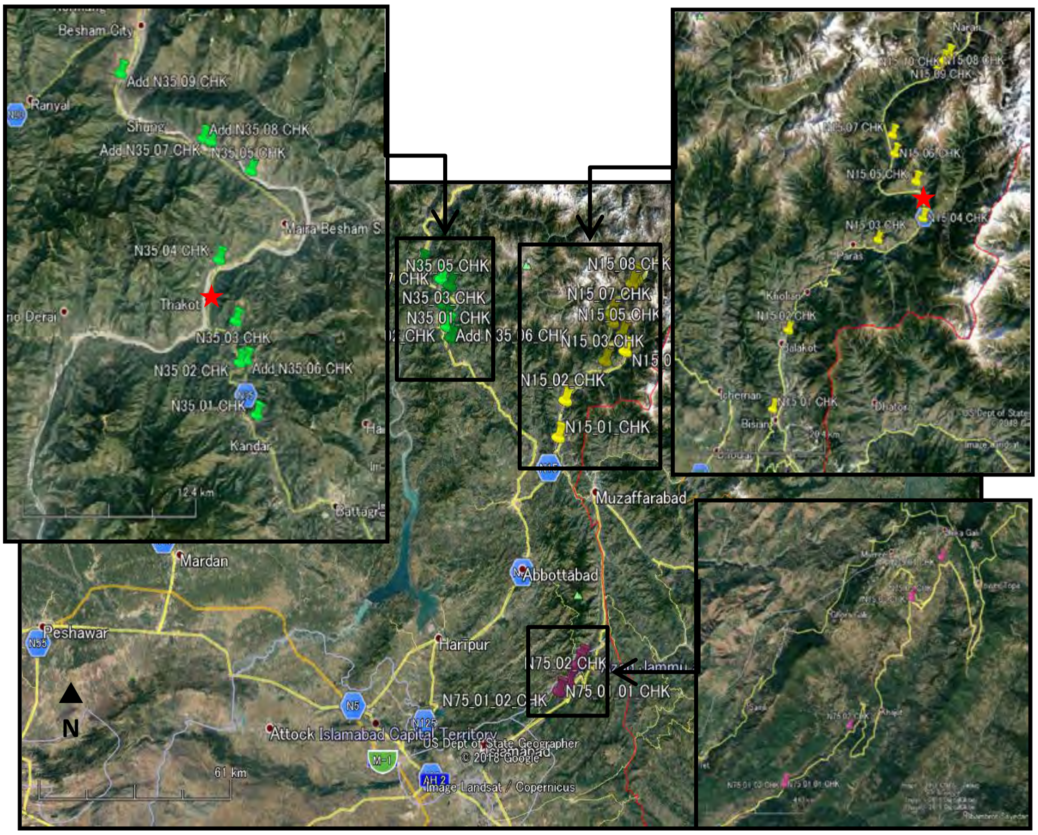
Figure 4.60 Coastal Protection Maintenance Cost Record at Ministry of Coastal Protection in Maldives

Source: JICA Survey Team

[51] JICA Disaster Reduction Main Streaming Hand Book 2013

4.6 Middle list

The sites that need countermeasure works, which are listed in the long list, created in 4.3, were selected within the non restricted area for the JST, considering the future implementation of landslide disaster countermeasure works. The long list sites located on N-15, N-35, and N-75 in the non restricted area are shown in the figure below.



LEGEND ★: Junction 📌: Sites on N15 📌: Sites on N35 📌: Sites on 75

Figure 4.61 Long List Sites (25 sites) of Non restricted Area Source: Modified from Google Earth

From these 25 sites, approximately 10 sites were selected as priority sites for future implementation of landslide disaster countermeasure works. These sites are assigned to the “middle list.”

To create the middle list, the following two evaluations were examined.

- Natural conditions evaluation
- Socioeconomic conditions evaluation

The natural conditions were judged by experts based on the field survey of each site. The following three items were reviewed: Hazard rank, evaluation of the possibility of disaster occurrence at present; disaster history rank, evaluation of the situation of impact on the road due to past disasters; and disaster scale rank, evaluation of the maximum scale of disaster expected for each disaster type.

The socioeconomic conditions were judged by experts based on the field survey at each site and data analysis, such as a road linear map. The socioeconomic conditions were evaluated through the following five items: Vehicle operating cost rank, evaluate the transportation expenses per unit time (“traffic volume” × “International Roughness Index IRI”); alternative road rank, evaluate the distance of an alternative route to be used in case of a disaster; connectivity rank, evaluate the accessibility to the road from the neighboring community; rank of constraints for route planning, evaluate geomorphological and geological constraints on the planning of the alternative route; and nearby hospital rank, evaluate road contribution in emergencies.

The evaluation methods and results based on each condition are described below.

4.6.1 Narrowing through Dangerousness of Disaster

a. Hazard Rank

For the hazard rank, experts judged based on the field survey of each site. In the on-site field survey, the evaluation was conducted focusing on the geomorphology, geology/soil, road surface condition, slope shape, deformations, effects of existing countermeasure works, etc. and are shown in the table below for each disaster type (slope failure, rockfall, and debris flow).

Table 4.24 Focus Points on Slope Failure and Rockfall for Hazard Rank

Major items		Minor items
Geomorphology		・ Talus slope ・ Clear knick line ・ Erosion of slope leg ・ Over hung ・ Water catchment terrain
Geology/soil	Soil	・ Erodible soil ・ Soil that is prone to weaken when containing water
	Bedrock	・ High density of cracks and weak layers ・ Erodible bedrock ・ Weathering-sensitive lithology
	Structure	・ Dip slope ・ Bedrock with hard upper part and fragile lower part
Surface conditions		・ Stability of topsoil, fragmented rock and boulders ・ Spring water condition ・ Covering condition of the surface
Slope shape		・ Height difference of slope ・ Gradient of slope
Deformations		・ Fall of rocks and small rock fall ・ Gully erosion, scouring, piping hole ・ Sinking, floor heave creep ・ Trunk curvature, fallen tree ・ Cracks, open cracks ・ Disturbance of countermeasure works
Countermeasure works		・ Effect of existing countermeasure works

Source: JICA Survey Team

Table 4.25 Focus Points on Debris Flow for Hazard Rank

Major items	Minor items
Characteristics of a mountain stream	・ Emission river basin areas: river basin areas with a river bed gradient of 15 degrees or more. ・ Steepest river bed gradient
Characteristics of slope	・ Slope areas with a slope gradient of 30 degrees or more. ・ The area occupied by grasslands and shrubs (tree height approximately 10 m or less) ・ Presence of earthworks accompanied by unstable earth and sand. ・ New cracks/ presence of main scarp ・ A relatively large-scale failure history
Countermeasure works	・ Effect of existing countermeasure works
Road structure	・ Width of flowing path ・ Girder height

Source: JICA Survey Team

The evaluation results were classified into three ranks: a, b, and c, based on the definitions shown in Table 4.26.

Table 4.26 Legend of Hazard Rank Evaluation

Rank	Definition
A	The possibility of occurrence of disaster at present is high
B	The possibility of occurrence of disaster at present is moderate
C	The possibility of occurrence of disaster at present is low

Source: JICA Survey Team

b. Disaster History Rank

Regarding the disaster history rank, the NHA personnel were interviewed at each site for the occurrence of landslide disasters that affected road traffic within the last 5 to 10 years. Ideally, the disaster history rank should be evaluated by organizing disaster scale, closed road section, etc. from a disaster history database that has been compiled. However, because these disaster history databases are not well organized by the NHA, the evaluation was made through interviews of the staff in charge.

The evaluation results were classified into three ranks: a, b, and c based on the definitions shown in Table 4.27.

Table 4.27 Legend of Disaster History Rank

Rank	Definition
A	Landslide disaster that occurred and reached the road and affected traffics
B	Landslide disaster that occurred and reached the road but hadn’t affected traffics
C	Landslide disasters occurred, but they hadn’t reached the road Landslide disasters have not occurred

Source: JICA Survey Team

c. Disaster Scale Rank

Regarding the disaster scale rank, the experts judged it based on the field survey at each site. In the field survey, the scale of the portion of the slope that is expected to be unstable at present was visually measured for each disaster type, as shown below, and the scale was estimated. In the field survey, the scale of the part that is presumed to be unstable at present is visually measured and estimated for each disaster type, as shown below.

Slope failure: size of slope of maximum unstable part Width(m) × Length of slope h(m) × Depth d(m)

Rock fall: size of maximum unstable rock Width(m) × Height h(m) × Depth d(m)

Debris flow: size of maximum unstable sediment Length(m) × Width w(m) × Depth d(m)

The evaluation results were classified into three ranks: a, b, and c, based on the definitions shown in Table 4.28 to Table 4.30. In addition, when there are two or more disaster types on the same slope, the higher rank (a > b > c) among the disasters was set as the rank of the site.

Table 4.28 Legend of Disaster Scale Rank for Slope Failure

Rank	Definition
a	5,000 m^3 or more
b	2,000–5,000 m^3
c	Less than 2,000 m^3

Source: JICA Survey Team

Table 4.29 Legend of Disaster Scale Rank for Rockfall

Rank	Definition
a	3 m^3 or more
b	1–3 m^3
c	Less than 1 m^3

Source: JICA Survey Team

Table 4.30 Legend of Disaster Scale Rank for Debris Flow

Rank	Definition
a	1,000 m^3 or more
b	500–1,000 m^3
c	Less than 500 m^3

Source: JICA Survey Team

d. Evaluation Result of Natural Condition

The evaluation results of hazard rank, disaster history rank, and disaster scale rank of the 25 sites of the long list, located within the non restricted area for the JST, are shown in Table 4.31.

Table 4.31 Evaluation Result of Natural Conditions

Number	Types of disaster	Hazard rank	Disaster history rank	Disaster scale rank	Disaster scale
N15_1	Slope failure + Debris flow	b	b	c	Debris flow：100 m (l) * 1 m (w) * 1 m (d) = 100 m^3 Slope failure：60 m (w) * 20 m (h) * 1 m (d) = 1200 m^3
N15_2	Slope failure	c	c	c	40 m (w) * 20 m (h) * 1 m (d) = 800 m^3
N15_3	Slope failure	a	a	a	400 m (w) * 300 m (h) * 1 m (d) = 120,000 m^3
N15_4	Slope failure +Rock fall	b	c	b	100 m (w) * 50 m (h) * 0.5 m (d) = 2,500 m^3 Maximum dimensions of fallen rock =3 m * 1 m * 1 m = 3 m^3
N15_5	Debris flow	a	a	a	200 m (l) * 3 m (w) * 2 (d) = 1,200 m^3
N15_6	Slope failure	a	a	a	50 m (w) * 100 m (h) * 2 m (d) = 10,000 m^3 Maximum dimensions of fallen rock =2 m * 1 m * 1 m = 2 m^3
N15_7	Debris flow	c	c	c	N/A
N15_8	Rock fall	a	a	a	Maximum dimensions of Rock fall = 2 m * 2 m * 2 m = 8 m^3
N15_9	Slope failure +Rock fall	a	a	a	100 m (w) * 120 m (h) * 1 m (d) = 12,000 m^3 Maximum dimensions of fallen rock = 2 m * 2 m * 2 m = 8 m^3
N15_10	Debris flow	a	a	a	200 m (l) * 4 m (w) * 2 (d) = 1,600 m^3 Maximum dimensions of boulder in a mountain stream = 4 m * 4 m * 2 m = 32 m^3
N35_1	Slope failure +Rock fall	b	b	a	100 m (w) * 60 m (h) * 1 m (d) = 6,000 m^3 Maximum dimensions of fragmented rock = 2 m * 2 m * 1.5 m = 6 m^3
N35_2	Slope failure +Rock fall	c	c	b	20 m (w) * 10 m (h) * 1 m (d) = 200 m^3 Maximum dimensions of fallen rock = 2 m * 1 m * 1 m = 2 m^3
N35_3	Debris flow	c	b	c	50 m (l) * 5 m (w) * 1 m (d) = 250 m^3
N35_4	Debris flow	c	c	c	N/A
N35_5	Debris flow	c	b	c	30 m (l) * 10 m (w) * 2 m (d) = 600 m^3
N35_6	Slope failure	b	c	c	50 m (w) * 30 m (h) * 0.5 m (d) = 750 m^3
N35_7	Rock fall	b	b	b	300 m (w) * 50 m (h) * 2 m (d) = 30,000 m^3 Maximum dimensions of Rock fall = 3 m * 2 m * 2 m = 12 m^3
N35_8	Rock fall	a	a	a	400 m (w) * 50 m (h) * 2 m (d) = 40,000 m^3 Maximum dimensions of Rock fall = 3 m * 2 m * 1 m = 6 m^3
N35_9	Debris flow	a	a	b	300 m (l) * 2 m (w) * 1 m (d) = 600 m^3
N75_1_1	Slope failure +Debris flow	c	c	c	Slope failure：20 m (w) * 10 m (h) * 0.5 m (d) = 100 m^2 Debris flow：20 (l) * 1 m (w) * 2 m (d) = 40 m^3
N75_1_2	Debris flow	c	c	c	N/A
N75_2	Slope failure	a	b	a	70 m (w) * 100 m (h) * 2 m (d) = 14,000 m^3
N75_3	Debris flow	c	c	c	100 m (l) * 2 m (w) * 1 m (d) = 200 m^3
N75_4	Debris flow	c	c	c	100 m (l) * 2 m (w) * 1 m (d) = 200 m^3
N75_5	Slope failure +Rock fall	a	b	a	Slope failure：60 m (w) * 60 m (h) * 1.5 m (d) = 5,400 m^3 Maximum dimensions of Rock fall = 2 m * 1 m * 1 m = 2 m^3

Source: JICA Survey Team

4.6.2 Narrowing through Socioeconomic Condition

a. Vehicle Operating Cost Rank

The vehicle operating cost rank represents the traffic cost in one day. Traffic costs in five representative sections from the survey target roads have been calculated and the rank has been determined according to each traffic cost. The Vehicle Operating Cost has been expressed in Rs. and the method of calculation is: "daily traffic" × "traffic cost per vehicle according to the road's IRI."

The survey for the vehicle operating cost was carried out considering N-15 as two sections, N-35 as two sections and N-75 as one section. The survey was carried out in one representative slope of each section. The divisions into sections were carried out in places where the traffic has changed considerably, such as cities and crossroads. The data and results obtained in the representative slopes were considered to be the same in other slopes located in the same section. The representative slopes, where the surveys were carried out and the other slopes they represent (where the data and results are considered to be the same) are shown in the table below.

Table 4.32 Representative Slopes where Vehicle Operating Cost Ranks were carried out and the Slopes they Represent

Representative slopes	Represented slopes
N15_2	N15_1, N15_2, N15_3, N15_4
N15_6	N15_5, N15_6, N15_7, N15_8, N15_9, N15_10
N35_2	N35_1, N35_2, N35_3, N35_6
N35_8	N35_4, N35_5, N35_7, N35_8, N35_9
N75_4	All slopes in N75

Source: JICA Survey Team

The "daily traffic" has been surveyed for one hour in each representative slope. Each vehicle that passed the slope during the hour was counted and classified as a small, medium, or big vehicle. The description of each type of vehicle is shown in the figure below. The actual measurement was carried out when the road traffic is thought to be the heaviest, in the morning until the afternoon. It should be noted that a "day-night traffic ratio" for 12 hours of day time and 12 hours of night time (the proportion of traffic at night in relation to the traffic during the day) was established per representative sections in order to take into consideration the difference in traffic between day time and night time. The ratio was set considering site inspections, information from the NHA staff, and the experience of an expert engineer. The daily traffic for each representative slope and the slopes they represent are shown in the table below.

"Daily traffic" (number of vehicles) = actual measurement (number of vehicles) × 12 (day time hours) + actual measurement (number of vehicles) × 12 (night time hours) × "day-night traffic ratio"

Category	Description	Example	
Small Vehicle	Motorcycle Small Sedan		
Medium Vehicle	Medium Sedan Wagon Sun Utility Vehecle		
Large Vehicle	Bus Trucks Lorry		

Figure 4.62 Description of Each Type of Vehicle Counted during the Actual Measurement

Source: JICA Survey Team

The "daily traffic" for each representative slope is shown in the table below.

Table 4.33 Daily traffic in Each Representative Slope

Representative slope	Type of vehicle	Actual measurement (number of vehicles)	Day-night traffic ratio	"Daily traffic" (number of vehicles)
N15_2	Small vehicles	124	0.2	1786
	Medium vehicles	69	0.2	994
	Big vehicles	8	0.2	115
	Total	201	-	2894
N15_6	Small vehicles	22	0.2	317
	Medium vehicles	18	0.2	259
	Big vehicles	3	0.2	43
	Total	45	-	619
N35_2	Small vehicles	116	0.5	2088
	Medium vehicles	73	0.5	1314
	Big vehicles	63	0.5	1134
	Total	252	0.5	4536
N35_8	Small vehicles	129	0.2	1858
	Medium vehicles	52	0.2	749
	Big vehicles	56	0.2	806
	Total	237	-	3413
N75_4	Small vehicles	275	0.5	4950
	Medium vehicles	122	0.5	2196
	Big vehicles	40	0.5	720
	Total	437	-	7866

Source: JICA Survey Team

The IRI is as a standard index to quantify road surface roughness. The traffic cost per vehicle and type of vehicle depending on the IRI is published by the NHA in its Annual Maintenance Plan Books. The IRI of each road section was set by an experienced engineer. A high IRI means a road with a high roughness surface and the rougher the road surface, the more expensive the traffic cost. The condition of the roads in the survey target area is relatively good, each having an IRI value of 4. The figure below describes the relation between the road surface condition and the IRI value.

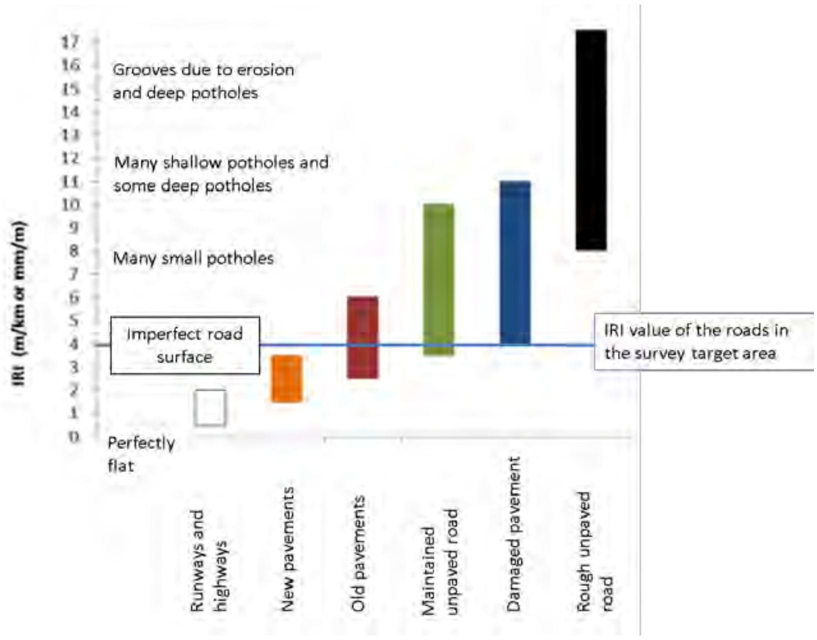


Figure 4.63 Relation Between IRI Values and Road Surface Condition IRI

Source: PWRC documents, 2014, 56-10

Table 4.34 Traffic Cost per Vehicle and Type of Vehicle for IRI = 4 based on NHA Annual Maintenance Plan 2016–2017

IRI	Small vehicle (Rs.)	Medium vehicle (Rs.)	Big vehicle (Rs.)
4	9.1	20.8	82.3

Source: JICA Survey Team

The vehicle operating cost per day for each representative slope that takes the traffic cost per vehicle and IRI and the “daily traffic” is shown in Table 4.35. The higher the vehicle operating cost is, the larger the effect on the socioeconomic factors will be if the road is affected and closed by a disaster.

Table 4.35 Daily Traffic, Traffic Cost per type of Vehicle and IRI, Traffic Cost per day and Type of Vehicle, and Daily Vehicle Operating Cost

Representative slope	Type of vehicle	Daily traffic (Number of vehicles)	Traffic cost per type of vehicle and IRI (Rs.)	Traffic cost per day and type of vehicle (Rs.)	Daily Vehicle Operating Cost (Rs.)
N15_2	Small vehicles	1786	9.1	16252.6	46,397
	Medium vehicles	994	20.8	20675.2	
	Big vehicles	115	82.3	9464.5	
	Total	2894	-	-	
N15_6	Small vehicles	317	9.1	2884.7	11,830
	Medium vehicles	259	20.8	5387.2	
	Big vehicles	43	82.3	3538.9	
	Total	619	-	-	
N35_2	Small vehicles	2088	9.1	19000.8	139,660
	Medium vehicles	1314	20.8	27331.2	
	Big vehicles	1134	82.3	93328.2	
	Total	4536	-	-	
N35_8	Small vehicles	1858	9.1	16907.8	98,846
	Medium vehicles	749	20.8	15579.2	
	Big vehicles	806	82.3	66333.8	
	Total	3413	-	-	
N75_4	Small vehicles	4950	9.1	45045	149,978
	Medium vehicles	2196	20.8	45676.8	
	Big vehicles	720	82.3	59256	
	Total	7866	-	-	

Source: JICA Survey Team

Based on the results of the survey, 3 ranks (3, 2, 1) were established as shown in the table below.

Table 4.36 Legend of Vehicle Operating Cost Rank

Rank	Definition
3	100,000 Rs. or more
2	40,000–100,000 Rs.
1	less than 40,000 Rs.

Source: JICA Survey Team

b. Alternative Road Rank

The alternative road rank, represents the possibility of using an alternative road in the case that the target road is closed owing to a disaster. It has been evaluated considering the distance that has to be travelled from the location where the disaster is expected to happen to the same point using the shortest alternative route. The figure below is an example of how the distance of the shortest alternative route for N75-4 was measured. It should be noted that the alternative route has to be able to bear the same amount of traffic as the road that is expected to be affected by a disaster. The distance was measured using GIS.

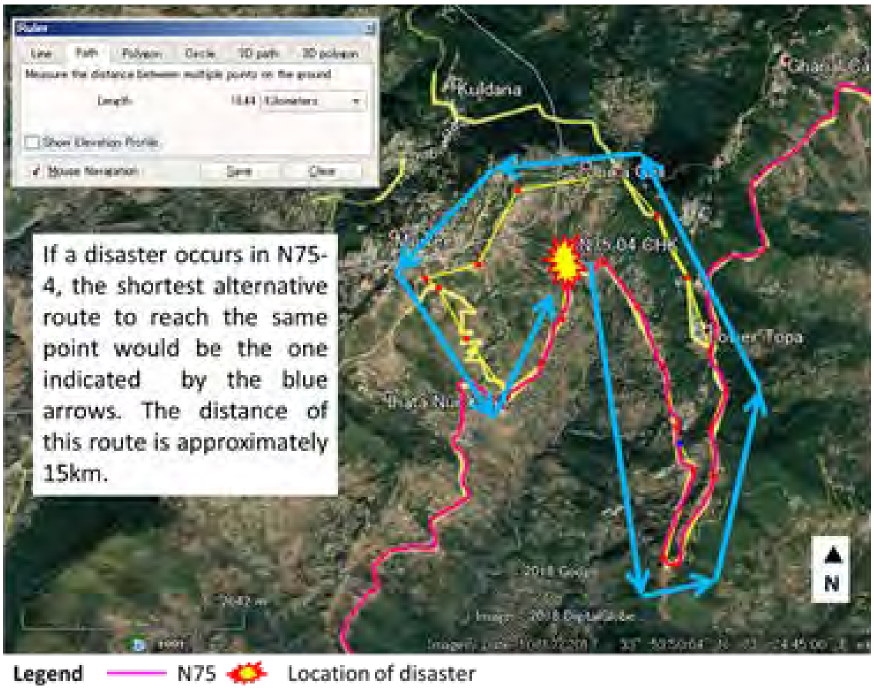


Figure 4.64 Schematic Figure of How to Measure the Distance of the Shortest Alternative Route with N75-4 as an example Source: Google Earth

The longer the alternative route the more the logistics suffer from delays and the greater the impact on socioeconomic factors. The table below shows the shortest alternative routes possible for each site in case of disaster occurrences.

Table 4.37 Shortest Alternative Route Possible for Each Site in Case of Disaster

Num.	Shortest alternative route possible
N15_1	Around 15 km SE from Attar Sheesha
N15_2	No possible alternative route shorter than 500 km from the N
N15_3	An alternative route is used in the opposite shore but trucks have difficulties to go through
N15_4	No possible alternative route shorter than 500 km from the N
N15_5	No possible alternative route shorter than 500 km from the N
N15_6	No possible alternative route shorter than 500 km from the N
N15_7	There is a bridge 1 km upstream
N15_8	No possible alternative route shorter than 500 km from the N
N15_9	No possible alternative route shorter than 500 km from the N
N15_10	No possible alternative route shorter than 500 km from the N
N35_1	No possible alternative route shorter than 500 km from the N
N35_2	No possible alternative route shorter than 500 km from the N
N35_3	No possible alternative route shorter than 500 km from the N
N35_4	The old bridge nearby can be used alternatively
N35_5	The Allai Road on the opposite shore can be used alternatively up to Besham
N35_6	No possible alternative route shorter than 500 km from the N
N35_7	The Allai Road on the opposite shore can be used alternatively up to Besham
N35_8	The Allai Road on the opposite shore can be used alternatively up to Besham
N35_9	There are alternative routes upstream and downstream no further than 1km
N75_1_1	Northern road (Approximately 50 km in length) can be used alternatively
N75_1_2	Northern road (Approximately 50 km in length) can be used alternatively
N75_2	Northern road (Approximately 50 km in length) can be used alternatively
N75_3	Northern road (Approximately 50 km in length) can be used alternatively
N75_4	The road that crosses Murree on top of the slope can be used alternatively (around 10 km)
N75_5	Northern road (Approximately 50 km in length) can be used alternatively

Source: JICA Survey Team

Based on the results of the survey, three ranks (3, 2, 1) were established, as shown in the table below.

Table 4.38 Legend of Alternative Road Rank

Rank	Definition
3	> 100 km
2	10–100 km
1	＜ 10 km

Source: JICA Survey Team

c. Connectivity Rank

The connectivity rank represents the connectivity of local communities to the road. It has been evaluated through the number of households nearby that would receive direct negative impact in the case in which a disaster occurs in the road that they live next to. The definition of households nearby was established as the number of households next to the road in the road section that comprises 500 m to both sides from the location where disaster is expected to happen. The counting of households was carried out through satellite imagery and inspected at the site. An example of how the counting of households was carried out is shown in the figure below. The table below shows the number of households nearby of each site.

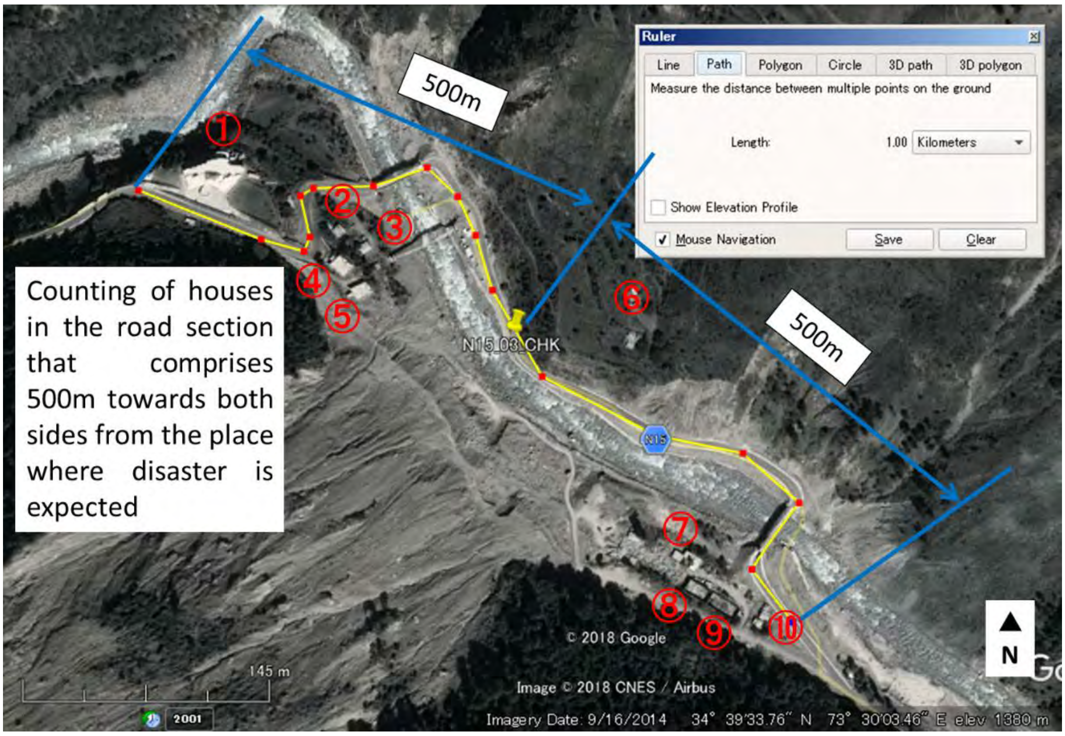


Figure 4.65 Schematic Figure of How the Counting of Households Nearby was carried out with N15_3 as an Example Source: Google Earth

Table 4.39 Number of Households Nearby Each Site

Num.	Local community (Num of households)
N15_1	Around 10
N15_2	Around 30
N15_3	Around 10
N15_4	None
N15_5	None
N15_6	None
N15_7	Around 100
N15_8	None
N15_9	None
N15_10	None
N35_1	None
N35_2	None
N35_3	None
N35_4	Around 50
N35_5	Around 10
N35_6	None
N35_7	None
N35_8	None
N35_9	Around 50
N75_1_1	None
N75_1_2	None
N75_2	Around 10
N75_3	Around 10
N75_4	Around 30
N75_5	Around 10

Source: JICA Survey Team

Based on the results of the survey, three ranks (3, 2, 1) were established, as shown in the table below.

Table 4.40 Legend of Connectivity Rank

Rank	Definition
3	Local community＞50 households
2	Local community 1-50 households
1	No local community

Source: JICA Survey Team

d. Rank of Constraints for Route Planning

The rank of constraints for route planning represents the constraints when improving the road from a geological/geomorphological point of view when planning an alternative route. The evaluation was carried out in two steps. The first step consisted on desktop work, interpreting satellite imagery for understanding the geomorphology of the site and its surroundings. The second step consisted of investigating the geological and geomorphological characteristics of the site and its surroundings on-site. The constraints for road improvement were considered given this information. Examples of constraints for road improvement are shown in the figures below.

Figure 4.66 Road can be shifted toward the Valley Side because there is enough flat space (Example in N15_8). It should be Noted that shifting the road does not mean the disaster can be avoided

Source: JICA Survey Team

Figure 4.67 Road cannot be shifted toward the Valley Side because there is not enough flat space (Example in N35_8)

Source: JICA Survey Team

Figure 4.68 Similar Road can be Constructed in the Opposite Shore (Detouring is Possible by Construction of a Bridge) (Example in N35_3)

Source: JICA Survey Team

Figure 4.69 Similar Road cannot be Constructed in the Opposite Shore because the Slope is too Steep. (Detouring is not Possible by Construction of a Bridge) (Example in N15_8)

Source: JICA Survey Team

With respect to route planning, the more constraints there are, the more difficult it will be to carry out the road improvement, such that the enactment of countermeasure works in these types of sites are priority. Table 4.41 shows the constraints and possible measures that could be taken at each site. It should be noted that highly expensive measures such as tunnels have not been considered.

Table 4.41 Constraints for Route Planning in Each Site

Num.	Constraints for route planning
N15_1	Given the type of disaster expected, the most cost-effective measure would be constructing a culvert. Removing the sediment may also be an option because the scale of disaster expected is small
N15_2	Given the characteristics of the disaster, the road may be maintained without constructing countermeasures
N15_3	Construction of countermeasures are thought to be the most cost-effective measure
N15_4	An alternative route can be constructed on the opposite shore, but the construction of countermeasures is thought to be the most cost-effective measure
N15_5	The construction of a bridge is necessary to avoid debris flow
N15_6	The road could be shifted to the top of the slope
N15_7	None
N15_8	Although the road can be shifted toward the valley side, rock falls cannot be avoided. Construction of countermeasures are thought to be the most cost-effective measure because there is not enough space on the opposite shore
N15_9	Construction of countermeasures is thought to be the most cost-effective measure
N15_10	Construction of a culvert and river training works are thought to be the most cost-effective measure
N35_1	Construction of countermeasures are thought to be the most cost-effective measure, although the road can be shifted to the opposite side of the slope
N35_2	Given the characteristics of the expect disaster, the road may be maintained without construction of countermeasures
N35_3	Construction of a culvert is thought to be the most cost-effective measure, although the road can be shifted to the opposite side of the slope
N35_4	The current section can be crossed only through a bridge
N35_5	Construction of a culvert is thought to be the most cost-effective measure, although the road can be shifted to the opposite side of the slope
N35_6	Construction of countermeasures are thought to be the most cost-effective measure, although the road can be shifted to the opposite side of the slope
N35_7	Construction of countermeasures are thought to be the most cost-effective measure, although the road can be shifted to the opposite side of the slope
N35_8	Construction of countermeasures are thought to be the most cost-effective measure, although the road can be shifted to the opposite side of the slope
N35_9	Construction of countermeasures are thought to be the most cost effective and appropriate measure because the current section is located in the middle of an urban area
N75_1_1	Countermeasures are not necessary
N75_1_2	Countermeasures are not necessary
N75_2	Construction of countermeasures are the most cost-effective and realistic measure
N75_3	Countermeasures are not necessary
N75_4	Countermeasures are not necessary
N75_5	The current section can be avoided by constructing a bridge but the construction of countermeasures is thought to be the most cost-effective measure

Source: JICA Survey Team

Based on the results of the survey, three ranks (3, 2, 1) were established, as shown in the table below.

Table 4.42 Legend of Rank of Constraints for Route Planning

Rank	Definition
3	・The flat surface where the actual road lays is too narrow; therefore, the road cannot be shifted to the valley side ・The road cannot be shifted to the opposite shore because it is very steep (detouring by bridge construction is not possible)
2	・The flat surface where the actual road lays is too narrow; therefore, the road cannot be shifted to the valley side ・The road can be shifted to the opposite shore (detouring by bridge construction is possible)
1	・The road can be shifted to the valley side because there is enough flat surface

Source: JICA Survey Team

e. Nearby Hospital Rank

The nearby hospital rank represents the contribution of the corresponding road section in emergency operation activities. If a landslide occurs, and closing the road generates casualties, the greater the distance of the nearest hospital is from the disaster site, the more difficult it will be for emergency services to carry out their functions. The method of evaluation was carried out measuring the distance of each site to the nearest hospital through national roads using GIS. It should be noted that the hospitals considered in this survey were those that had hospitalization facilities, several medical departments, and those that could give basic medical emergency services. Clinics were not considered in the scope of this rank. The information and locations of the hospitals that apply to the description of hospital given above were given by the NHA staff in charge of each section. The table below shows the distance between each site and the nearest hospital.

Table 4.43 Distance between Each Site and Nearest Hospital

Num.	Distance to the nearest hospital
N15_1	The nearest hospital is around 10 km to the N in Balakot
N15_2	There is a hospital in Balakot within 1km
N15_3	The nearest hospital is around 25 km to the S in Balakot
N15_4	The nearest hostpital is around 25 km to the S in Balakot
N15_5	The nearest hostpital is around 35 km to the S in Balakot
N15_6	The nearest hostpital is around 45 km to the S in Balakot
N15_7	The nearest hostpital is around 50 km to the S in Balakot
N15_8	The nearest hostpital is around 65 km to the S in Balakot
N15_9	The nearest hostpital is around 65 km to the S in Balakot
N15_10	The nearest hostpital is around 70 km to the S in Balakot
N35_1	The nearest hospital is around 10 km to the S in Battagram
N35_2	The nearest hospital is around 10 km to the S in Battagram
N35_3	The nearest hospital is around 15 km to the S in Battagram
N35_4	The nearest hospital is around 20 km to the S in Battagram
N35_5	The nearest hospital is around 30 km to the S in Battagram
N35_6	The nearest hospital is around 10 km to the S in Battagram
N35_7	The nearest hospital is around 35 km to the S in Battagram
N35_8	The nearest hospital is around 35 km to the S in Battagram
N35_9	The nearest hospital is around 40 km to the S in Battagram
N75_1_1	The nearest hospital is around 15 km to the NE in Murree
N75_1_2	The nearest hospital is around 15 km to the NE in Murree
N75_2	The nearest hospital is around 10 km to the NE in Murree
N75_3	There is a hospital in Murree within 2 km
N75_4	There is a hospital in Murree within 2 km
N75_5	There is a hospital in Murree within 2 km

Source: JICA Survey Team

Based on the results of the survey, three ranks (3, 2, 1) were established, as shown in the table below.

Table 4.44 Legend of Nearby Hospital Rank

Rank	Definition
3	>30 km
2	10–30 km
1	<10 km

Source: JICA Survey Team

f. Results of the evaluation of the socioeconomic conditions

The establishment of the thresholds for each rank of each socioeconomic factor was set relatively in three levels by an expert, giving the highest rank to the sites where a disaster would cause the greatest damage to socioeconomic factors.

The results of the five ranks of the socioeconomic factors evaluated given to each of the 25 sites in the long list are shown in the table below.

Table 4.45 Results of Evaluation of Socioeconomic Factors

Num.	Type of disaster	Vehicle Operating Cost Rank	Alternative Road Rank	Connectivity Rank	Rank of Constraints for Route Planning	Nearby Hospital Rank
N15_1	Slope failure + Debris flow	2	2	2	1	1
N15_2	Slope failure	2	3	2	1	1
N15_3	Slope failure	2	3	2	2	2
N15_4	Slope failure +Rock fall	2	3	1	2	2
N15_5	Debris flow	1	3	1	3	3
N15_6	Slope failure	1	3	1	1	3
N15_7	Debris flow	1	1	3	1	3
N15_8	Rock fall	1	3	1	3	3
N15_9	Slope failure +Rock fall	1	3	1	2	3
N15_10	Debris flow	1	3	1	2	3
N35_1	Slope failure +Rock fall	3	3	1	2	1
N35_2	Slope failure +Rock fall	3	3	1	1	1
N35_3	Debris flow	3	3	1	2	2
N35_4	Debris flow	2	1	2	3	2
N35_5	Debris flow	2	2	2	2	3
N35_6	Slope failure	3	3	1	1	1
N35_7	Rock fall	2	2	1	2	3
N35_8	Rock fall	2	2	1	2	3
N35_9	Debris flow	2	1	2	3	3
N75_1_1	Slope failure +Debris flow	3	2	1	1	2
N75_1_2	Debris flow	3	2	1	1	2
N75_2	Slope failure	3	2	2	3	1
N75_3	Debris flow	3	2	2	1	1
N75_4	Debris flow	3	1	2	1	1
N75_5	Slope failure +Rock fall	3	2	2	2	1

Source: JICA Survey Team

4.6.3 Overall Evaluation

In order to prepare the middle list, an overall evaluation was carried out by integrating the natural conditions and the socioeconomic conditions respectively.

The natural conditions were evaluated in three ranks: A, B, C by a combination of the evaluation rank (a, b and c) of the "hazard rank," "disaster history rank," and "disaster scale rank." The potential disaster for landslide disasters in the section is evaluated as A (maximum), B (moderate), and C (minimum) respectively.

The overall evaluation of socioeconomic condition was determined by the summation (5 to 15) of the ranks (1 to 3) of “Vehicle Operating Cost Rank,” “Alternative Road Rank,” “Connectivity Rank,” “Rank of constraints for route planning,” and “Nearby Hospital Rank.” The higher the summation of the ranks, the greater the socioeconomic impact when landslide disasters occur in that section.

Table 4.46 Legend of Overall Evaluation of Natural Conditions

Rank	Definition
A	In the case there is/are one or more “a”s
B	In the case there are one or more “b”s and no “a”s
C	In the case there are all “c”s

Source: JICA Survey Team

The overall evaluation results of the 25 long list sites located within the non restricted area for Japanese are as shown in the Table 4.47. A high overall evaluation means that the priority of implementation of the landslide disaster countermeasure work is high. The sites with natural condition rank A were set as sites of the middle list.

Table 4.47 Overall Evaluation Results

Number	Types of diasaster	Natural Conditions Evaluation			Socioeconomical Conditions Evaluation					Comprehensive Evaluation	
		Hazaed Rank	Disaster History Rank	Disaster Scale Rank	Vehicle Operating Cost Rank	Alternative Road Rank	Connectivity Rank	Rank of constraints for route planning	Nearby Hospital Rank	Natural Conditions	Sosioeconomical Conditions
N15_1	Debris flow +Slope failure	b	b	c	2	2	2	1	1	B	8
N15_2	Slope failure	c	c	c	2	3	2	1	1	C	9
N15_3	Slope failure	a	a	a	2	3	2	2	2	A	11
N15_4	Slope failure +Rock fall	b	c	b	2	3	1	2	2	B	10
N15_5	Debris flow	a	a	a	1	3	1	3	3	A	11
N15_6	Slope failure	a	a	a	1	3	1	1	3	A	9
N15_7	Debris flow	c	c	c	1	1	3	1	3	C	9
N15_8	Rock fall	a	a	a	1	3	1	3	3	A	11
N15_9	Slope failure +Rock fall	a	a	a	1	3	1	2	3	A	10
N15_10	Debris flow	a	a	a	1	3	1	2	3	A	10
N35_1	Slope failure +Rock fall	b	b	a	3	3	1	2	1	A	10
N35_2	Slope failure +Rock fall	c	c	b	3	3	1	1	1	B	9
N35_3	Debris flow	c	b	c	3	3	1	2	2	B	11
N35_4	Debris flow	c	c	c	2	1	2	3	2	C	10
N35_5	Debris flow	c	b	c	2	2	2	2	3	B	11
N35_6	Slope failure	b	c	c	3	3	1	1	1	B	9
N35_7	Rock fall	b	b	b	2	2	1	2	3	B	10
N35_8	Rock fall	a	a	a	2	2	1	2	3	A	10
N35_9	Debris flow	a	a	b	2	1	2	3	3	A	11
N75_1_1	Slope failure +Debris flow	c	c	c	3	2	1	1	2	C	9
N75_1_2	Debris flow	c	c	c	3	2	1	1	2	C	9
N75_2	Slope failure	a	b	a	3	2	2	3	1	A	11
N75_3	Debris flow	c	c	c	3	2	2	1	1	C	9
N75_4	Debris flow	c	c	c	3	1	2	1	1	C	8
N75_5	Slope failure +Rock fall	a	b	a	3	2	2	2	1	A	10

Source: JICA Survey Team

4.7 Short List

The short list was created in order to consider the implementation of future landslide disaster countermeasure works from the middle list created as explained in 4.6. The short list should consist of a maximum of five to six sites. In creating the short list, the following three conditions were examined in this work.

- Constraints of countermeasure work implementation
- Prospected methods of countermeasures (only the evaluations “A” or “B” in the “natural conditions” indicated in 4.6)
- Prospected design and construction systems (only the evaluation “A” or “B” in the “natural conditions” indicated in 4.6)

“Constraints of countermeasure work implementation” was checked by the on-site field survey and hearing investigation regarding the following five items at each site:
a) China construction section, whether the site corresponds to the section, which is under construction by the Chinese government’s financial cooperation; b) difficulty of transportation during winter, whether road transportation is possible in the case of heavy snow or avalanches in winter; c) presence of underground facilities and objects, whether optical fibers and water pipes are buried in the national highway of the relevant section; d) presence of private land, whether the areas of slopes to be measured are located on private lands; and e) ground survey targets, whether ground drilling survey has been conducted during this survey.

In the “Prospected methods of countermeasures,” the prospected countermeasure areas, only those that corresponds to "A" or "B" in the "natural condition" indicated in 4.6., and methods were judged by the experts.

In the “Prospected design and construction systems,” the relative difficulty of design, the predicted contractors (or countries of construction) and built-to-order systems were judged by the experts only for those which correspond to "A" or "B" in the "natural condition" indicated in 4.6.

The three conditions are control points to discuss the feasibility for the countermeasure construction. “Constraints” that prevent implementing the countermeasures and unenforceable “methods” and “design and construction systems” in Pakistan should be removed from the short list in advance.

The results of each evaluation are shown below.

4.7.1 Constraint on Countermeasure Works Implementation

a. China construction section

In some sections of the national highways in Pakistan, construction of road widening, tunnels, bridges, and other works are currently being carried out through the financial cooperation of the Chinese government. In addition, along the national roads of mountainous areas, a dam construction is being carried out. Therefore, the slopes in these sections, judged to be high risks at present are expected to disappear because these areas will have a new route by the constructions of tunnels and bridges, cuts of mountain side slopes will be implemented by widening of roads, and current roads will be buried by the dam construction. For these reasons, the slopes that correspond to these sections were confirmed by the on-site field surveys and were excluded from the short list.

As a result of the surveys, part of N-35 corresponding to these construction sections, road widening works, tunnels and bridges constructions were implemented at N35_1, N35_2, N35_3, and there was a dam construction site at N35_6. The corresponding sections are shown below.

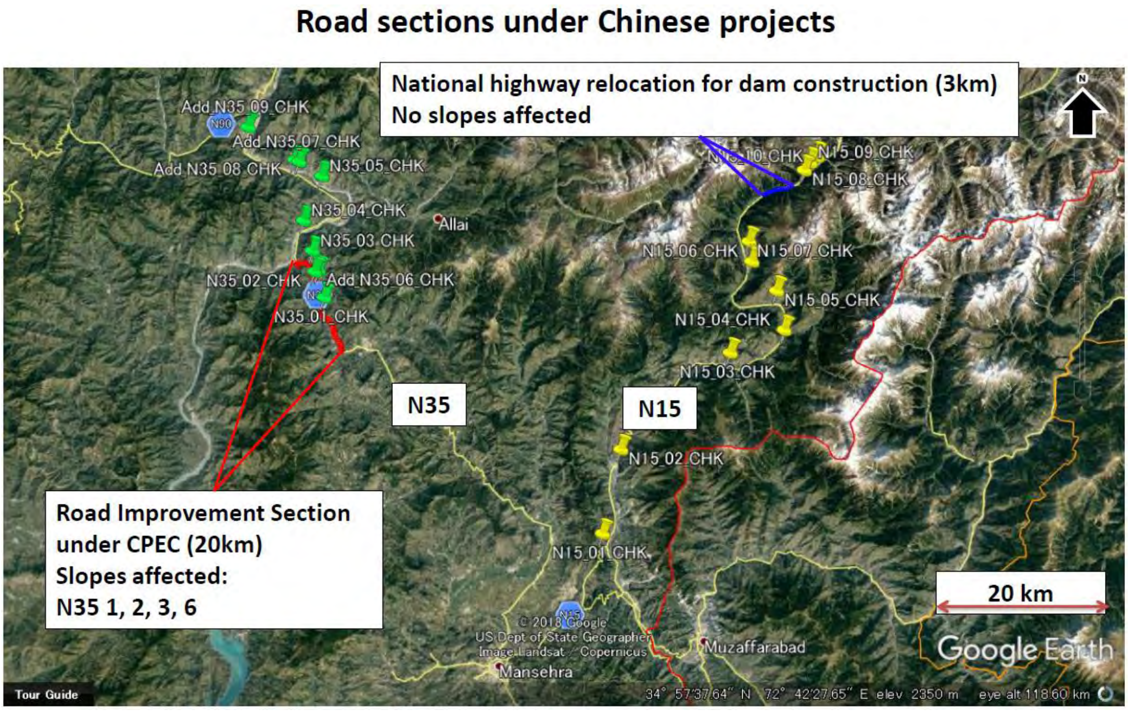


Figure 4.70 Financial Cooperation Work Section along the National Highway by the Chinese Government Source: Google Earth

b. Difficulty of transportation during winter

The feasibility of road traffic cuts due to heavy snow and avalanches in winter were confirmed by the hearing investigations with NHA officials.

The results of the surveys indicated that there may be a possibility to not be able to go through along the road at the mountainous areas of N-15 in the winter season (December to March). They also indicated that there may be a possibility of temporarily closing the road in the mountain pass section of N-15 in the snowiest season (around February).

The sections or roads expected to be impassable in winter (December to March) are N15-8, N15-9, and N15-10, and those expected to have temporarily closed roads during the snowiest season (around February) are N15_4 and N15_5.

c. Presence of underground facilities and objects,

The existence of optical fibers and water pipes buried in the national roads were confirmed from the hearing investigation to NHA staff.

The results of the surveys indicated that optical fibers and water pipes were buried in all of the surveyed sites.

d. Presence of private land

It was confirmed in the hearing investigation to NHA staff if the targeted parts of the mountain side slopes or valley side slopes (embankment) belong to private lands.

As a result of the investigation, there is possibility that part of the target slopes of N75_2, N75_5 belong to private lands.

e. Ground survey targets

In this survey, simple boring surveys were conducted to confirm the soil properties and N values. The boring surveys were conducted at five locations: N15_3, N15_6, N15_8, N15_9, and N75_2.

4.7.2 Prospected Landslide Countermeasure Works

The basic flowchart of selecting the possible countermeasure methods for the six slopes (short list) is as follows.

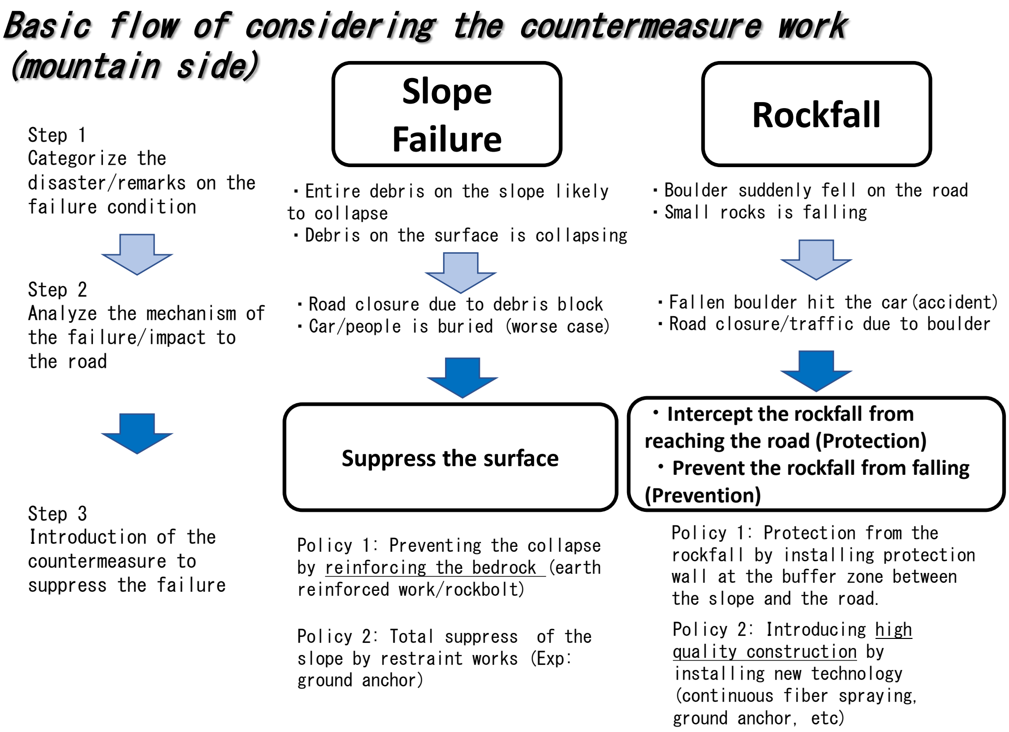


Figure 4.71 Basic Flowchart of Selecting the Countermeasure Methods on the Mountain Side

Source: JICA Survey Team

Slope failures and rockfalls were remarkable on the mountain side. Slope failure refers to the phenomenon in which the surface of the weathered and loosened rock or debris collapsed when these are triggered by the increase of surface water and groundwater during snow melting and rainy season. [Rockfall refers to a phenomenon in which a part of a rock or boulder detached from the steep rockwall falls on the road. The suitable countermeasure method was selected considering the characteristics of the disasters (slope failure when the surface soil collapse, and rockfall when the detached boulder falls).

The items below were considered for the Slope failure.

1) Slope reprofilling (cutting): slope will be reprofilled (cutting) into a stable gradient (repose angle) based on the slope material (rock or debris)
2) The inverted construction method will be applied, in which the cutting will be carried out stepwise (cutting and countermeasure at each one step) from the upper side of the slope. The safety of the construction can be secured through this method as the period of exposing the slope

is shorter than the other methods.

3) Shotcrete will be applied at the stable ground beneath the estimated slip surface which should be steady on the stable gradient. In case the landmass above the stable ground is thin, the reinforced earth method will be applied by penetrating rockbolts in the ground. The ground anchor will be used in case the landmass above the stable ground is thick.

The items below were considered for the rockfall

1) In addition to the geological factor (generation of the rockfall from the steep slope) of the rockfall, the isolation of the road from the slope shall be considered. The construction of the protection walls on the buffer zone (if any) will be effective (protection work).
2) In the case that there is no buffer zone between the road and the slope, spraying on the slope can be applied to prevent the rockfall (prevention work).

3) From the methods mentioned above, the new technology, such as ground anchor and fiber spraying, will increase the stability of the slopes. In addition to these two methods, Geo-Rockwall (rockfall protection method), which consists of three different sandbags, is recommendable as it can absorb a massive shock and can be constructed using waste soil at the site[52].

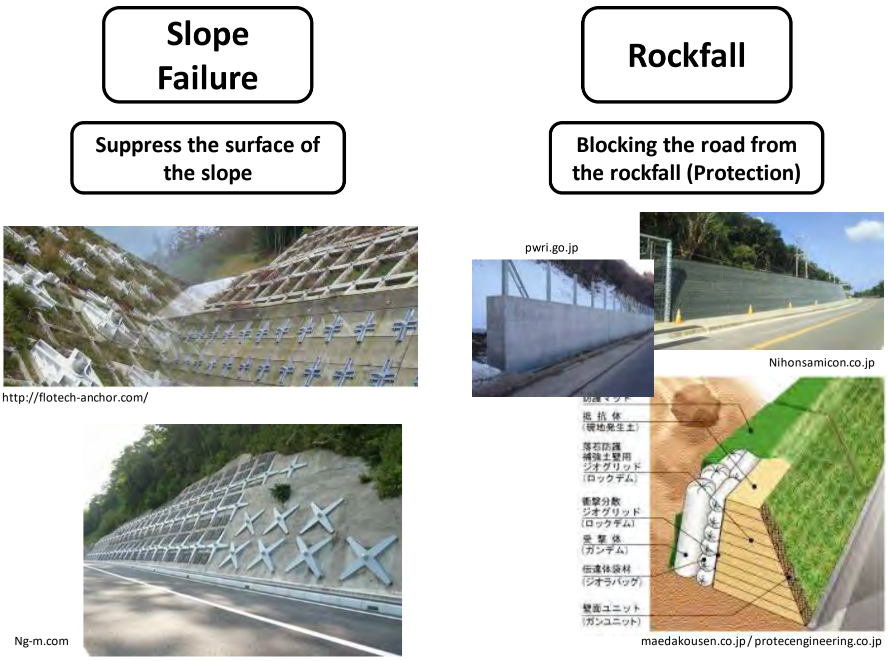


Figure 4.72 Image of Countermeasure Works on the Mountain Side

Source: JICA Survey Team

[52] http://www.proteng.co.jp/product_detail.php?keyno=14

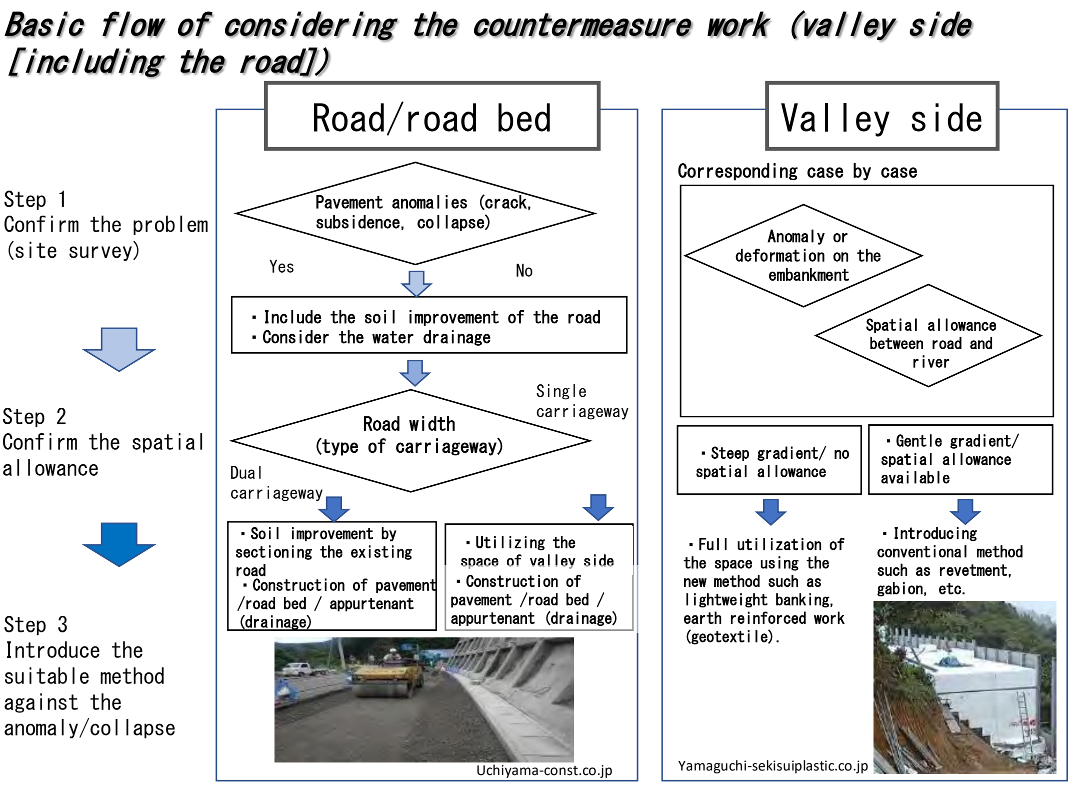


Figure 4.73 Basic Flowchart of Selecting the Countermeasure Methods on the Valley Side

Source: JICA Survey Team

As for the valley side (including the road facilities), the collapse of road embankments due to failures of surface water treatment on roads (infiltration from the crack in the ditch) were remarkable at N-75. In addition, the existence of road irregularities or subsidence (asphalt/flexible pavement), steps at the joint and horseshoe shaped cracks (concrete/rigid pavement), and spatial constraints between the valley side and river (height and length between the road and river) was considered in the selection of countermeasure methods. Lane restriction of road during the road construction was also considered based on the distance between the existing road and shoulder on the valley side. Specifically, the countermeasure methods were selected based on the points below.

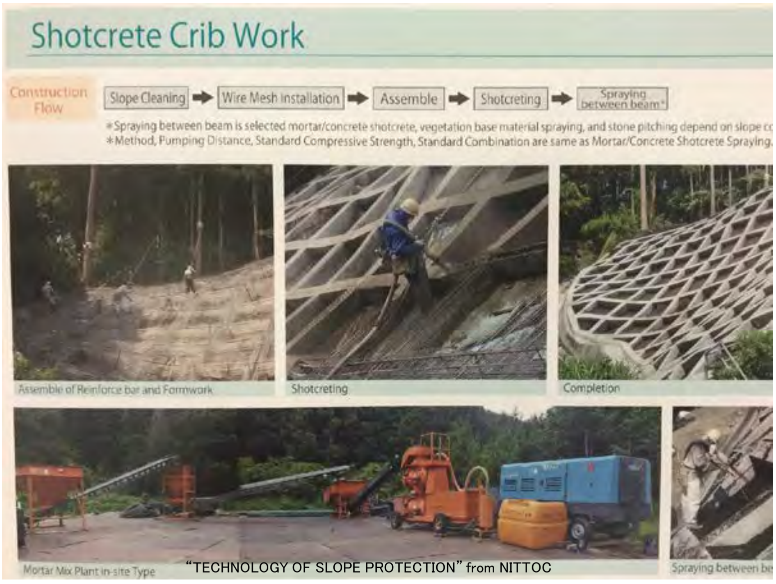
1) If the ground anomalies, such as subsidence or cavity on the road surfaces were suspected, the soil improvement (i.e., calcareous lime mixing) shall be carried out to optimize the consisted materials and improve the bearing capacity. By adopting this method, the pavement can last for a longer period as it can prevent the surface water infiltration and weakening of the road bed.
2) As for the embankments on the valley side, the countermeasure methods will be selected based on the spatial constraints between roads and the river. The conventional method (revetment work or erosion protection work) will be applied if there is enough space. If the space is limited, lightweight banking (i.e., EPS[53] or FCB[54] method, etc.), reinforced earth work utilizing geotextile[55] can be recommended as it can be adopted on steep embankment slopes. EPS and FCB methods can reduce the volume weight of the road embankment to 1/30 of the conventional method (extremely light). In addition to its lightweight material, it has compression resistance and water resistance, and it is easy to construct (precast). This method can be differentiated from

[53] http://www.sekisuiplastics.co.jp/prdt/eps/eps_index.html
[54] http://www.fcb-ken.e-const.jp/fcbsetumei.html
[55] https://www.maedakosen.jp/mdk/construction/reinforced-earth

the other methods used in the site and it is recommendable[56)57)].

The selected countermeasure methods are described in the table below.

Table 4.48 Selected Countermeasure Methods (1/4)

Method	Mortar/Concrete Shotcrete Spraying
Diagram	 "TECHNOLOGY OF SLOPE PROTECTION" from NITTOC
Explanation	Mixture of continuous fiber (polystyrene), sand, soil, and water will be sprayed onto the unstable slope, forming a thick layer and unify the slope and the continuous fiber reinforced soil. It is usually adopted for the mountain side cuttings to prevent erosion, weathering, and surface collapse.
Method	Shotcrete Crib Work
Diagram	 "TECHNOLOGY OF SLOPE PROTECTION" from NITTOC
Explanation	Slope stabilization method in which the grid frame is installed on the unstable slope. Wire mesh grid is frequently used for a grid frame and can be divided into on-site installation type or precast type. This method can be combined with vegetation mat, shotcrete spraying, rockbolts, ground anchor, etc.

56 https://www.hokukon.co.jp/catalog/data/ro/eps.pdf
57 https://www.achilles.jp/product/construction/civil-work/eps-method/

Table 4.49 Selected Countermeasure Method (2/4)

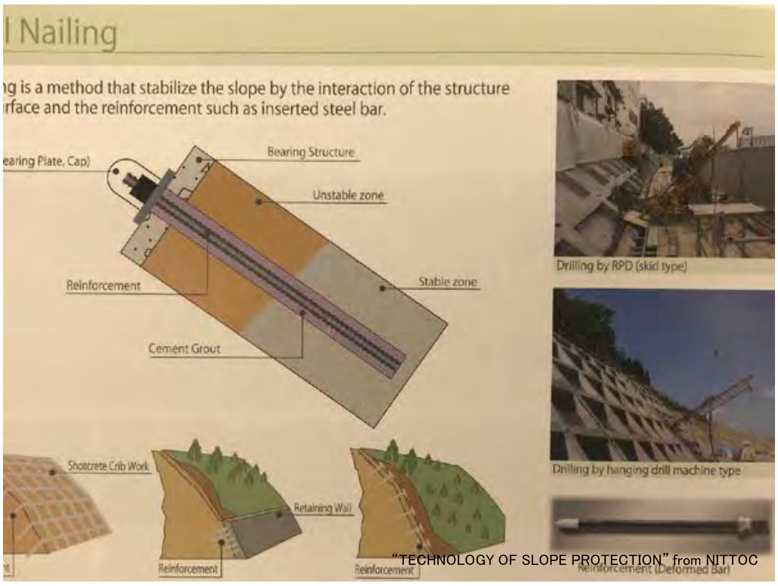
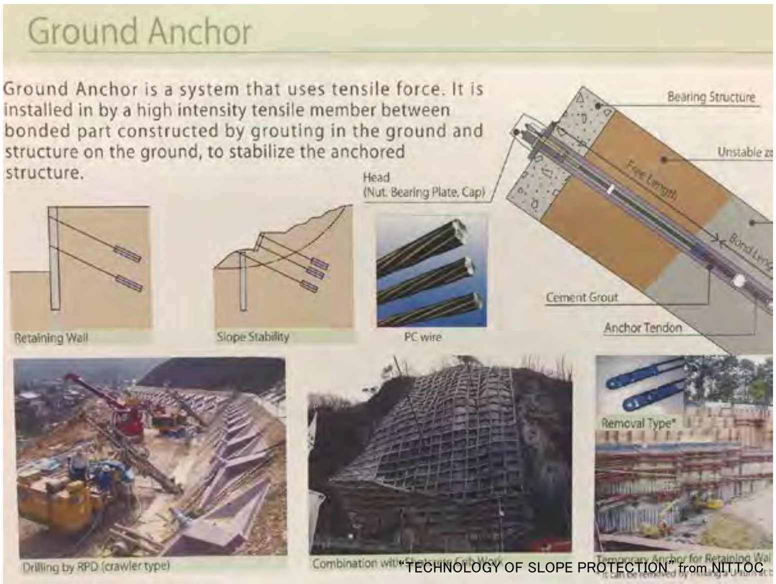
Method	Reinforced Earth Work/Rockbolt
Diagram	"TECHNOLOGY OF SLOPE PROTECTION" from NITTOC
Explanation	Steel bar (rockbolt) penetrates the stable ground along with the mortar to stabilize the unstable slope by the tensile strength. Dynamically, the resistance force of the rockbolt restrains the force of the moving landmass. This method can be adopted at the steep slope (exceeding the stable gradient), which can also reduce the cutting volume and preserve the vegetation of the slope.
Method	Ground Anchor
Diagram	"TECHNOLOGY OF SLOPE PROTECTION" from NITTOC
Explanation	Ground anchors stabilize the slope by installing high-intensity pc wire that has a large resistance force. The bonded part (anchored zone) constructed by grouting in the ground and the anchor tendon is fix to the surface using the bearing plate. The tensile strength can be adjusted at the head of the ground anchor. Therefore, the safety factor (one of the concepts of quality performance indicators that compare the ratio of the moving force and the restraining force) of the slope can be managed artificially depending on the situation. In addition, it is an innovative infrastructure technology, as the shape and material of the bearing plate can be further developed.

Table 4.50 Selected Countermeasure Method (3/4)

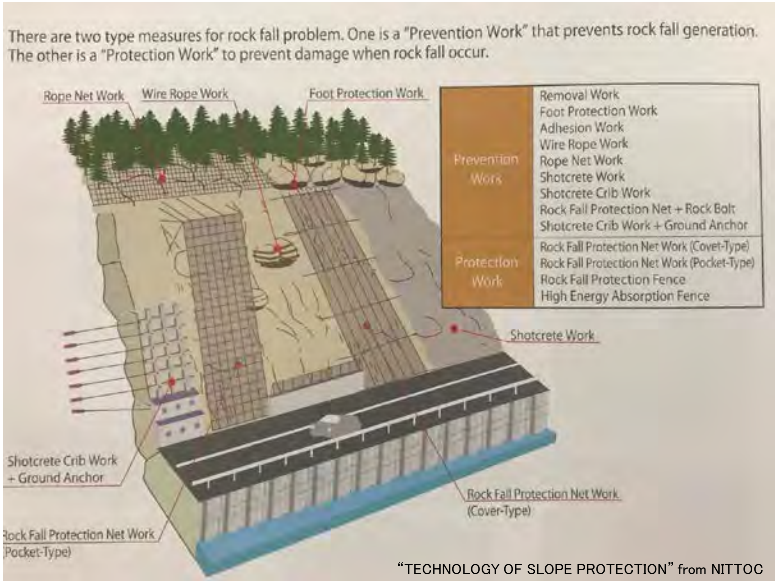
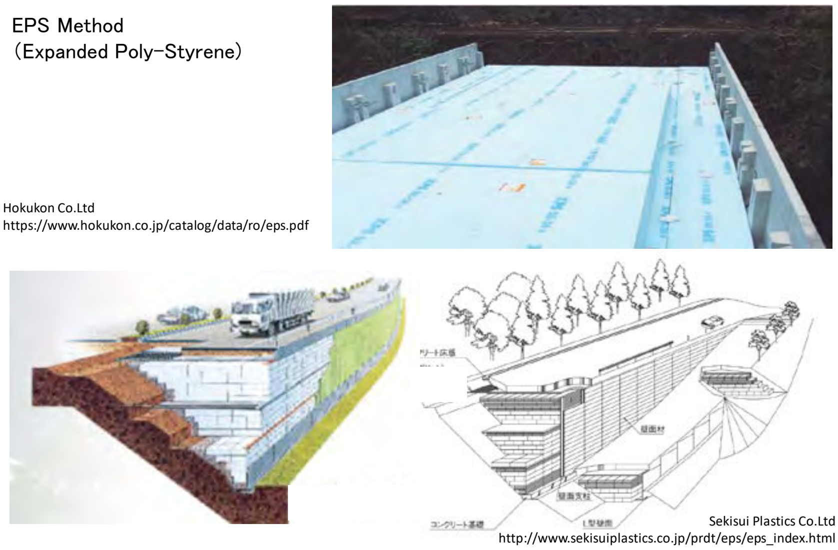
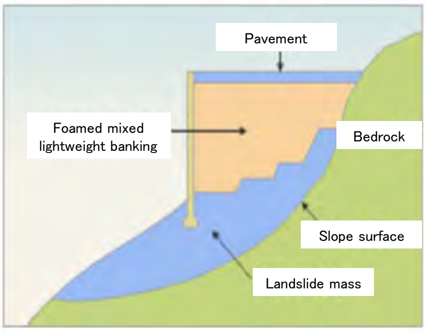
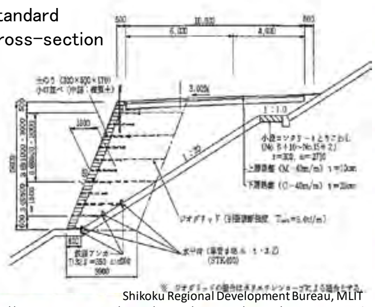
<table>
<tr><th>Method</th><th>Rockfall Prevention/Protection Work</th></tr>
<tr><td>Diagram</td><td>
</td></tr>
<tr><td>Explanation</td><td>There are two countermeasures for Rockfalls, which are prevention work that prevents Rockfall generation (restrain the detached rock using shotcrete spraying and crib work, or using rock net), and protection work to prevent damage when the Rockfall occurs (protect the rock from reaching the road). Based on the discussion with the Pakistani professor of geotechnical engineering, the concept of Rockfall protection/prevention work is new in Pakistan. Therefore, the new method of Rockfall protection work shall be introduced at the candidate site (N15_8).</td></tr>
<tr><th>Method</th><th>Lightweight Banking Method (Expanded Polystyrene, EPS)</th></tr>
<tr><td>Diagram</td><td>
</td></tr>
<tr><td>Explanation</td><td>EPS is a method in which polystyrene is used in a civil engineering structure. Taking advantage of its characteristics (light weight, self-reliance, workability), this method can be adopted for embankments, backfilling of retaining wall/bridge foundation in a soft ground, or steep slopes. There are two manufacturing methods for EPS, which are framing and injection.</td></tr>
</table>

Table 4.51 Selected Countermeasure Methods (4/4)

Method	Lightweight Banking Method (Foamed Cement Banking, FCB)
Diagram	FCB Method（Foamed Cement Banking）  Foam created from the foam gun  During construction    http://www.fcb-ken.e-const.jp/fcbsetumei.html
Explanation	Foamed cement banking (FCB) methods utilize foamed cement [air-milk (air mortar)]. Owing to its characteristics (light weight, fluidity, and self-reliance), it can be adopted for the soft ground and embankments within landslide, embankments at the steep slope, backfill of the structure and any other places, where there are difficulties in using normal soil.
Method	Reinforced Earth Method
Diagram	Installation of geo grid  Installation of front wall  After construction  Standard Cross-section  Shikoku Regional Development Bureau, MLIT http://www.skr.mlit.go.jp/yongi/duties/research/douro/m_F-01_03.pdf
Explanation	Reinforced earth methods stabilize the earth structure by mixing the reinforced material to increase the strength of the soil. The reinforced materials for the embankment include steel material, geotextile, and mixed fiber, which are utilized in backfilling of terre armee and embankments. These materials are reinforced for tensile, compression, shear, and bending. The internal stability (stability within the reinforce range) and external stability (stability outside of the reinforce range) shall be considered during the designing of the reinforced materials.

Based on the points mentioned above, the possible countermeasure works at the six slopes (short list) were selected as follows.

Table 4.52 Possible Countermeasure Works at the Short List Slopes (1/3)

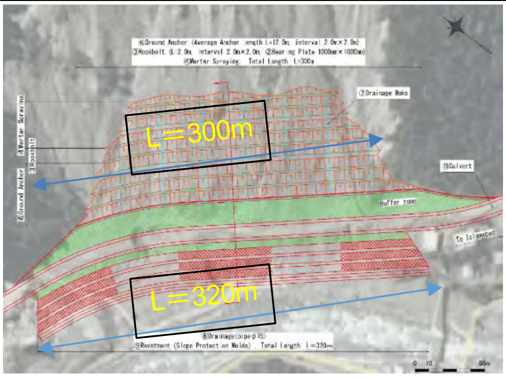
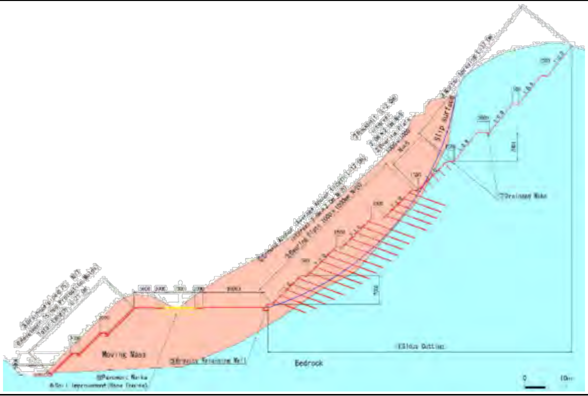
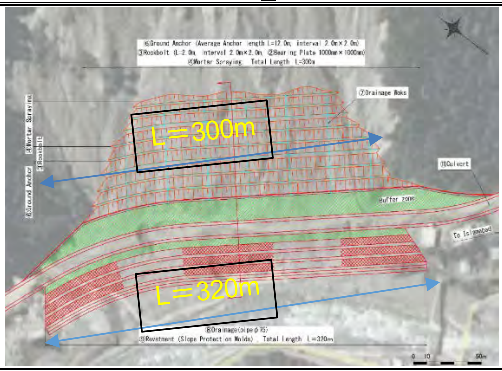
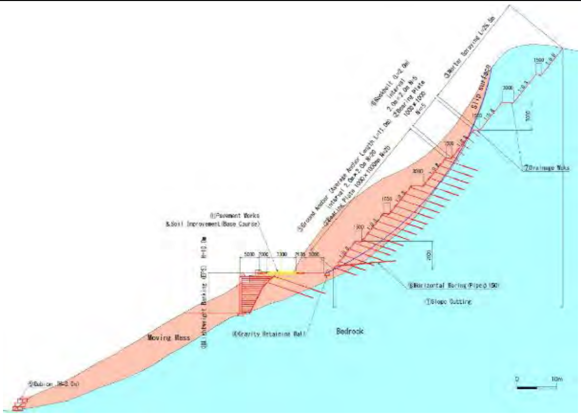
Slope		N15_3
Plan View		
Typical Cross-Section		
Methods	Mountain	Crib Work, Rockbolt, Shotcrete Spray, Retaining wall, Ground Anchor
	Valley	Revetment Work, Road Pavement (soil improvement)
Slope		N15_6
Plan View		
Typical Cross-Section		
Methods	Mountain	Crib Work, Rockbolt, Shotcrete Spray, Ground Anchor
	Valley	Gabion, Retaining wall, Lightweight Banking (EPS), Road Pavement (soil improvement)

Table 4.53 Possible Countermeasure Works at the Short List Slopes (2/3)

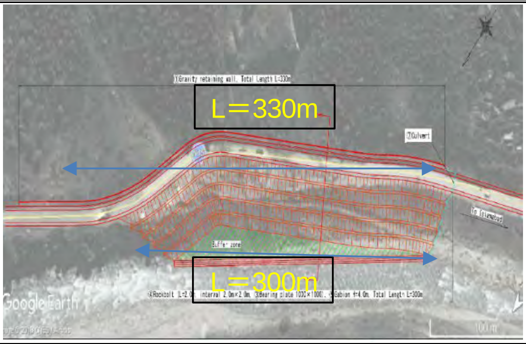
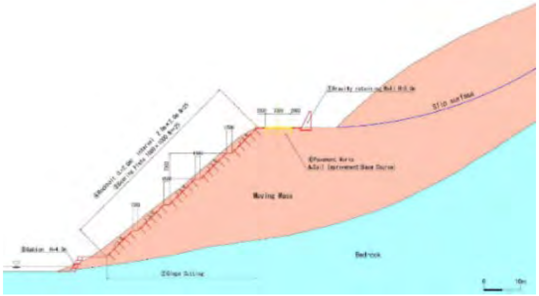
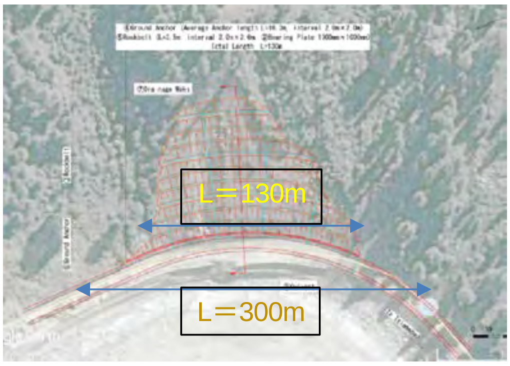
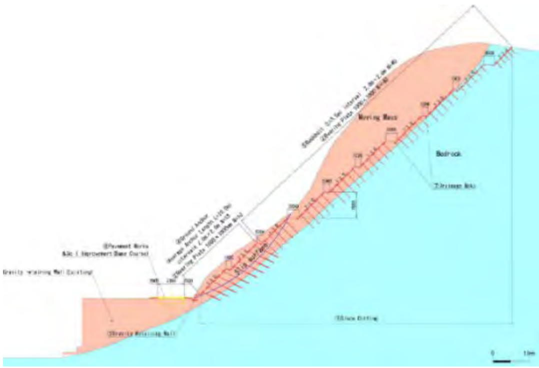
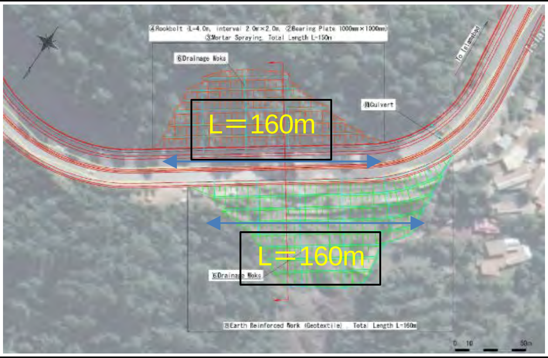
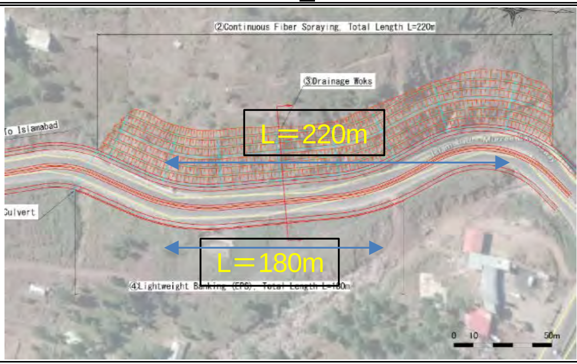
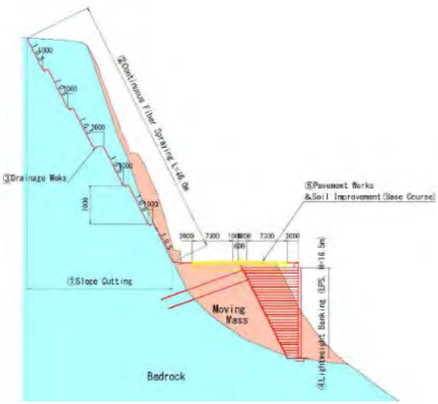
Slope		N15_8
Plan View		
Typical Cross-Section		
Methods	Mountain	Gravity type retaining wall
	Valley	Crib Work , Rockbolt, Gabion, Road Pavement (soil improvement)
Slope		**N15_9**
Plan View		
Typical Cross-Section		
Methods	Mountain	Crib Work, Shotcrete Spray, Rockbolt, Retaining wall
	Valley	Crib Work, Ground Anchor, Rockbolt, Road Pavement (soil improvement), Retaining wall

Table 4.54 Possible Countermeasure Works at the Short List Slopes (3/3)

Slope		N75_2
Plan View		
Typical Cross-Section		
Methods	Mountain	Crib Work, Shotcrete Spray, Rockbolt, Retaining wall
	Valley	Embankment Reinforced Earth Method (Geotextile), Road Pavement (soil improvement)
Slope		N75_5
Plan View		
Typical Cross-Section		
Methods	Mountain	Continuous Fiber Spray
	Valley	Lightweight Banking (EPS), Road Pavement (soil improvement)

4.7.3 Prospected Design and Construction Systems

a. Relative difficulty of design

The actual implementation of slope countermeasure works in Pakistan by utilizing the "4.7.2 Prospected Landslide Countermeasure Methods," were classified by design difficulty as "high" and "low." The following methods have some complications to calculate the load, etc., and are completely new concepts in Pakistan. Therefore, the relative difficulty of design was set to "high" for parts/sites that include these countermeasure methods, and the rest were set to "low."

- Anchor works
- Rockbolt works
- Geo rock wall works
- Bridge works

b. Construction system

Construction systems for "4.7.2 Prospected Landslide Countermeasure Methods," were classified into the following three.

A) Implementation by Japanese companies, providing technical guidance for local companies that would work as local contractor.

B) Implementation by local companies is possible; however, establishment and improvement of their technology are expected to be carried out by the implementation of the technical transfer to NHA, etc. from Japanese.

C) Implementation by the local companies with their actual techniques.

The following construction methods are complicated to construct and are completely new concepts in Pakistan. Therefore, the parts/sites that include these construction methods were set as construction system "A."

- Anchor works
- Rockbolt works
- Geo rock wall works
- Bridge works
- Groundwater drainage work (Horizontal boring)
- Lightweight banking works (Expanded Poly-styrene Construction)
- Roving wall works
- Embankment reinforcement earthworks (Geotextile)

Although the difficulty of design and construction itself is not high, as it is impossible for the local companies to plan the specifications of countermeasures (scale, strength, quantity, etc.), the sites that have these difficulties were set as construction system "B."

4.7.4 Short List

Based on the above considerations, the short list was set as follows.

- Overall evaluation of natural conditions is "A"
- Overall evaluation of socioeconomic conditions is "9" or more
- Exclude Chinese project construction sections
- Relative difficulty of design is “high” (from the survey and design stage, considerable technical support from the Japanese side is required)
- Construction systems is “A: Implemented by Japanese companies, providing technical guidance for local companies that would work as local contractor.”
- Slope countermeasure structures are being planned (excluding N15_5 countermeasures of debris flow “bridge”).

As a result, six sites were assigned to the short list to determine where to implement countermeasures preferentially on the premise of financial cooperation.

- N15_3 Slope failure
- N15_6 Slope failure
- N15_8 Rockfall
- N15_9 Slope failure + Rockfall
- N75_2 Slope failure
- N75_5 Slope failure + Rockfall

The selection list for the short list is shown on the next page.

Table 4.55 Selection List of the Short List

No.	Type of disaster	Natural Factors Evaluation			Socioeconomic factors evaluation					Overall evaluation		Remarks					Countermeasure			Short list (recommendation)
		Hazard rank	Disaster history rank	Disaster scale rank	Vehicle operating cost rank	Alternative road rank	Connectivity rank	Route planning constraints rank	Nearby hospitals rank	Natural factors	Socioeconomic factors	Chinese Projects Section	Road closure in winter	Underground facility (optical fiber, water pipe)	Including private land	Geological survey	Area for countermeasures	Method and quantity	Contractor	
N15_1	Debris flow + slope failure	b	b	c	2	2	2	1	1	B	8			○			①Debris flow: Road length=50m ②Slope failure: 60m(w)*20m(h)	①Concrete pavement, Roadbed improvement (Improvement of water durability in roadbed and pavement for debris flow. Construction of culverts is expensive because embankment is needed.) ②Retaining wall with rockfall fence or Rockfall fence (60m)	①Pakistan ②Pakistan (Equipment provision and technical transfer from Japan)	
N15_2	Slope failure	c	c	c	2	3	2	1	1	C	9			○						
N15_3	Slope failure	a	a	a	2	3	2	2	2	A	11			○		Drilling (8m): SPT, soil contents	400m(w)*100m(h)*20m(d)	Mountain side: Cut slope (1:1.5), Crib works + Shotcrete (sealing/long fiber) + Ground anchor works, Bioengineering, Drainage works, Approach road Valley side: Revetment works (400m), Embankment, Replacement of suspension bridge (120m)	Japan (Ground anchor works, methodology of construction)	◎
N15_4	Slope failure + rock fall	b	c	b	2	3	1	2	2	B	10		△	○			100m(w)*50m(h)、50m(w)*50m(h)	Retaining wall with rockfall fence or Rockfall fence (100m＋50m), Removal of unstable rocks	Pakistan (Equipment provision and technical transfer from Japan)	
N15_5	Debris flow	a	a	a	1	3	1	3	3	A	11		△	○			Road length=40m	New bridge(300m, pile foundation or Deep foundation for embankment) Valley side: Retaining wall + Embankment (improved soil for bridge foundation) + Ground anchor works Concern for construction: Risk of temporary works under narrow part and high location.	Japan (Investigation and design of bridge, Risk of temporary works)	
N15_6	Slope failure	a	a	a	1	3	1	1	3	A	9			○		Drilling (8m): SPT, soil contents	200m(w)*100m(h)*10m(d)	Mountain side: Cut slope (1:1.5), Groundwater drainage works (Horizontal drilling), Crib works + Shotcrete (sealing/long fiber) + Ground anchor works Valley side: Revetment works (200m), Retaining wall, Lightweight embankment (Expanded Poly-Styrol) Road: Culvert improvement, Drainage pavement, Drainage work of embankment	Japan (Groundwater drainage works (Horizontal drilling), Ground anchor works, Expanded Poly-Styrol)	◎
N15_7	Debris flow	c	c	c	1	1	3	1	3	C	9			○						
N15_8	Rock fall	a	a	a	1	3	1	3	3	A	11		○	○		Drilling (8m): SPT, soil contents	Road length=250m	Mountain side: Rockfall protection wall (ex. Geo Rock Wall) (250m) Valley side: Road relocation (250m), Revetment works Road: Drainage pavement, Improvement of ditch	Japan (Rockfall protection)	◎
N15_9	Slope failure + rock fall	a	a	a	1	3	1	2	3	A	10		○	○		Drilling (8m): SPT, soil contents	100m(w)*120m(h)*20m(d)、50m(w)*100m(h)*20m(d)	Mountain side: Cut slope (1:1.2)、Crib works + Shotcrete (sealing/long fiber) + Ground anchor works Valley side: Revetment works (150m), Retaining wall + Ground anchor works Road: Concrete pavement	Japan (Ground anchor works, Shotcrete (sealing/long fiber))	◎
N15_10	Debris flow	a	a	a	1	3	1	2	3	A	10		○	○			Road length=120m	Road: Concrete pavement, Roadbed improvement (Improvement of water durability in roadbed and pavement for debris flow.)	Pakistan	
N35_1	Slope failure + rock fall	b	b	a	3	3	1	2	1	A	10	× (Road improvement)		○			200m(w)*60m(h)*3m(d)	Mountain side: Crib works + Shotcrete (sealing/long fiber) , Drainage pipe Valley side: Retaining wall + Ground anchor works	Japan (Ground anchor works, Shotcrete (sealing/long fiber))	
N35_2	Slope failure + rock fall	c	c	b	3	3	1	1	1	B	9	× (Road improvement)		○			50m(w)*20m(h)*3m(d)	Mountain side: Rockfall net	Pakistan (Equipment provision and technical transfer from Japan)	
N35_3	Debris flow	c	b	c	3	3	1	2	2	B	11	× (Road improvement)		○			Culvert=1m*1m	Dredging of sediment in the valley and the culvert, road pavement	Pakistan	
N35_4	Debris flow	c	c	c	1	1	3	3	2	C	10			○						
N35_5	Debris flow	c	b	c	1	3	2	2	3	B	11			○			Culvert=0.5m*0.5m、Road length40m	Road: Concrete pavement, Ditch construction, Culvert construction, Roadbed improvement	Pakistan	
N35_6	Slope failure	b	c	c	1	3	1	2	2	B	9	× (Power dam)		○			Road length=30m	Shotcrete (sealing/long fiber) or Crib works + Bioengineering	Pakistan	
N35_7	Rock fall	b	b	b	1	3	1	2	3	B	10			○			300m(w)*50m(h)	Cut slope (including removal of unstable rocks, Rockfall net or Shotcrete (sealing/long fiber)	Japan (Rockfall protection)	
N35_8	Rock fall	a	a	a	1	3	1	2	3	A	10			○			400m(w)*50m(h)	Cut slope (including removal of unstable rocks, Rockfall net or Shotcrete (sealing/long fiber)	Japan (Rockfall protection)	
N35_9	Debris flow	a	a	b	1	1	3	3	3	A	11			○			Road length=40m	Embankment (100m) + Box culvert (2m×2m: 2 sets) Channel works (upstream: 500m, downstream: 300m, 2m×2m)	Pakistan	
N75_1_1	Slope failure + debris flow	c	c	c	3	2	1	1	2	C	9			○						
N75_1_2	Debris flow	c	c	c	3	2	1	1	2	C	9			○						
N75_2	Slope failure	a	b	a	3	2	2	3	1	A	11			○	○	Drilling (8m): SPT, soil contents	160m(w)*100m(h)*10m?(d)	Detailed investigation/analysis (Drilling, monitoring, stability analysis): Confirmation of slip surface Mountain side: Cut slope, Crib works + Rock bolts (70m) Valley side: Retaining wall, Improvement of embankment (Geotextile), Ground anchor works (by the stability analysis) Road: Drainage pavement, Improvement of ditch, Culvert	Japan (Improvement of embankment (Geotextile), Rock bolts)	◎
N75_3	Debris flow	c	c	c	3	2	2	1	1	C	9			○						
N75_4	Debris flow	c	c	c	3	1	2	1	1	C	8			○						
N75_5	Slope failure + rock fall	a	b	a	3	2	2	2	1	A	10			○	○	○	①Mountain side: 150m(w)*30m(h) ②Valley side: 60m(w)*60m(h)	①Cut slope, Shotcrete (sealing/long fiber) ②Removal of concrete wall, Crib works (60m) + Ground anchor works	Pakistan (Equipment provision and technical transfer from Japan)	◎

5 Recommendations of the Future Assistance Policies

In this chapter, based on the results reviewed in the previous chapters, future assistance policies are proposed. The assistance policies are primarily divided into “implementation of countermeasures by financial cooperation” (described in section 5.2) and “the capacity development by technical cooperation projects, etc.” (described in section 5.3). The issues related to landslide countermeasure works in Pakistan's national highway are discussed in section 5.1, and recommendations are proposed.

5.1 Organizing the Issues of Road Landslide Countermeasures

In Pakistan, there is a high frequency of natural disasters, such as floods, earthquakes, landslide disasters, and cyclones. Specifically, in KP and Northern PJ, given severe geographical conditions including steep mountainous areas and repeated natural disasters (for e.g., heavy rains and earthquakes), landslide disasters occur annually in the road infrastructures and constitute the basis of economic activity. Significant structural countermeasures (i.e., infrastructural measures) are not implemented relative to the aforementioned landslide disasters, and technical measures (for e.g., the adoption of traffic restrictions in advance) are not established. Based on the above background, issues on landslide disasters countermeasures in Pakistan's national highway are organized as follows.

1. Lack of investigation, analysis, and monitoring technology for landslide disasters.

   Given the current circumstances, the effects of the countermeasure are limited because the countermeasures are implemented without understanding the causes and mechanisms of landslide disasters. Thus, there is still a high risk that disasters can continuously occur at the countermeasure implementation sites in the future. Therefore, it is initially necessary to transfer the technology for the investigation, analysis, and monitoring of landslides. Thus, road administrators can observe the types of countermeasure methods that are effective and independently consider construction methods in the future by understanding the causes and mechanisms of landslides.

2. The master plan of road landslides countermeasures does not exist.

   Currently, NHA mainly implements "post-mitigation measures" including the removal of earth and sand from sites where landslide disasters occur. Thus, effective budget allocation is not implemented. Additionally, past disaster records are not systematically managed, and efficient and transparent reviews are not conducted in the countermeasure review plan process. Therefore, it is necessary to prepare a master plan for road landslide disaster countermeasures to evaluate slope stability and type of disasters (for e.g., simplified slope chart) and prioritize countermeasures based on the landslide disaster risk. This aids in planning an effective budget based on prioritizing countermeasures and implementing "pre-mitigation measures" in areas with high slope disaster risk. The preparation of a master plan for road landslide disaster countermeasures based on a slope chart aids in reviewing NHA’s landslide management system and proposing recommendations to improve it.

3. The effective structural countermeasures (infrastructural measures) have not been implemented against these landslide disasters.

   Structural countermeasures (for e.g., infrastructural measures) are not implemented in high-risk areas of landslide disasters (for e.g., slope failures, rockfalls, landslides, and debris flows). Furthermore, structural countermeasures range from large-scale and small to medium-scale landslide disasters as described below.

3-1: There exists a high possibility of road closure for a long period if landslide disasters occur on slopes with slope lengths corresponding to or exceeding several hundred meters. However, it is difficult to ascertain whether NHA implements sufficiently effective structural countermeasures relative to the aforementioned large-scale landslide disasters given the circumstances. It is necessary to implement countermeasures including deterrents (for e.g., anchors and rockbolts) introduced from Japan after understanding causes and mechanisms for the occurrence of landslides. This results in improving the safety of road traffic and preventing economic loss due to road closures.

3-2: Rockfalls involving a scale of several meters and slope failures corresponding to approximately ten meters occur frequently following heavy rainfall. However, it is difficult to ascertain whether NHA implements sufficiently effective structural countermeasures relative to the aforementioned small to medium-scale landslide disasters. Many of the disasters can be prevented by providing technical guidance of “locally applicable” countermeasures and applying technology currently used in Pakistan. For example, three examples detailing the application of the technology are as follows: 1) Reinforcement and effective arrangement of retaining walls and gabions; 2) efficient drainage facilities installations, such as culverts, drainage pipes, and flow path works; and 3) consideration of the gradient of cut earth due to differences in geology/geological structures. Effective countermeasures can be implemented at a low cost in a short time via the implementation of the “locally applicable” countermeasures,.

4. Technical measures, such as traffic restrictions in advance of landslide disaster, have not been established.

   Currently, only "post traffic regulation" (which implies, "When landslide disasters occur, the road will be closed until sediment removal is completed at the site.") is implemented. Thus, traffic closures suddenly occur everywhere following heavy rainfall. The implementation of countermeasures on all road slopes is practically impossible because of limited budget and personnel. Therefore, at high-risk sites, it is necessary to implement countermeasures, such as preliminary traffic regulation, to reduce landslide disasters risk to national roads and neighboring residents. The construction of a preliminary traffic regulation system (early warning system) and introduction of the concept of land utilization plan based on landslide disaster risk assessment improves road traffic safety and reduces economic loss due to sudden traffic closure.

Landslide disaster countermeasures for national highways in Pakistan can be divided into financial and technical cooperation. Financial cooperation is efficacious relative to the issue detailed in 3-1: “Effective structural countermeasures (infrastructural measures) are not implemented relative to landslide disasters” by performing road dslide countermeasures. Additionally, technical cooperation including project type technical cooperation that leads to capacity development in NHA is desirable.

Propositions on road landslide countermeasures (which are desirable for financial cooperation) are discussed in section 5.2: “Road Landslide Countermeasures (Draft)”. A proposition for technical cooperation is described in section 5.3: “Capacity development of Road Landslide Countermeasures”. The issues and proposed measures are summarized in the following table.

Table 5.1 Issues and proposed measures on landslide disaster

<table>
<tr><th></th><th>Issue</th><th colspan="3">Proposed measure</th></tr>
<tr><td>1</td><td>Lack of investigation, analysis and monitoring technology for landslide disasters</td><td colspan="3">Capacity development on investigation, analysis and monitoring for landslide disasters → 5.3</td></tr>
<tr><td>2</td><td>The master plan of road landslides countermeasures does not exist</td><td colspan="3">Capacity development on creation of the master plan for road landslide countermeasures → 5.3</td></tr>
<tr><td rowspan="2">3</td><td rowspan="2">The effective structural countermeasures (infrastructural measures) have not been implemented against these landslide disasters</td><td>3-1</td><td>Large</td><td>Construction of road landslide countermeasures → 5.2</td></tr>
<tr><td>3-2</td><td>Middle to small</td><td>Capacity development on implementation of structural countermeasures for small to medium-scale landslide disasters → 5.3</td></tr>
<tr><td>4</td><td>Technical measures, such as traffic restrictions in advance of landslide disaster, have not been established</td><td colspan="3">Capacity development on preparation of preliminary traffic regulation → 5.3</td></tr>
</table>

5.2 Road Landslide Countermeasures (Draft) (Results of Geotechnical investigation, countermeasure cross section figure, cost estimation)

The session considers options of financial cooperation by JICA relative to the issues described in section 5.1: "3-1: Effective structural countermeasures (infrastructural measures) are not implemented relative to landslide disasters".

In terms of a financial cooperation option for landslide disaster countermeasures for national highways in Pakistan, the most realistic countermeasure involves identifying high risk components and planning and implementing effective structural countermeasures based on a geotechnical survey. With respect to parts of the high-risk zone on landslide disasters, six slopes were selected based on natural and social conditions as detailed in Chapter 4. The outline of the geotechnical survey results for the slopes, countermeasure works, and pre-conditions for financial cooperation are described below

5.2.1 Results from Geotechnical Survey

A geotechnical survey was implemented in the six slopes that were selected for the short list. The boring points (i.e., edge of a road on the mountain side and point determined based on site situation) were determined in advance via the survey team. The Auger boring method was implemented in conjunction with a standard penetration test (approximately 8 m) to examine soil characteristics (hardness/softness) beneath a road. Electrical prospecting was also implemented with the boring survey as a supplementary survey to determine the boundary of the slip surface. Given time and financial restraints, the geotechnical survey was only implemented in five slopes (i.e., N15_3, N15_6, N15_8, N15_9, and N75_2) that were selected in advance. The survey was supervised by a Pakistani professor from the University of Engineering and Technology of Taxila (Mr. Naveed Ahmad) who received his Ph.D. (Geotechnical Engineering) from the University of Tokyo. The following table lists the depth of the estimated slip surface (boundary of the stable ground and moving mass). The results are reflected in the typical cross-section of each slope.

Table 5.2 Estimated Depth of the Slip surface from the Standard Penetration Test

Slopes	N15_3	N15_6	N15_8	N15_9	N75_2
Estimated depth of the slip surface [m]	Approximately 10m based on the result of electrical prospecting	5-7 m from the road	6–8 m from the road	4–7 m from the road	2–3 m from the road

Source: JICA Survey Team

Detailed results of the geotechnical investigation are attached in Appendix 5.

On 75_5 which is out of scope of the contract for geotechnical investigation can not be described here because short list of N75-5 was conducted after the completion of the contract.

The main results from each site are described below. As part of the geotechnical investigation of percussion drilling, factors including standard penetration, moisture content ratio, specific gravity, and liquid limit were observed.

On N15_3, the debris mainly included a composite of dolomite deposits from the surface to a depth of 1 m, and bedrock was observed at depths between 1 m and 7 m. Slope failure occurred several years prior to the observations.

On N15_6, materials used to make the road embankment and debris deposits were observed from the surface to a depth of 1.5 m, and bedrock was observed beneath this to a depth of 7 m.

On N15_8, only loose material (debris or part of landslide mass) was observed from the surface to a depth of 7.5 m.

On N15_9, loose soil (primarily the materials from road embankment) were observed from the surface to a depth of 2.8 m, and debris was observed beneath this to a depth of 5.5 m. With further increases in the depth, hard rock (deemed as bedrock) was observed between depths of 5.5 m and 7 m.

On N75_2, loose debris deposits were observed from the surface to a depth of 3.0 m. Observations for depths exceeding 3.0 could not be performed because drilling to greater depths was stacked.

5.2.2 Countermeasure works

Countermeasure works for each slope of the short list were drawn (plan view and typical cross-section) based on the result of the slope chart and geotechnical survey as mentioned above. Subsequently, the drawing was used to calculate the approximate cost of countermeasure for each slope. The following table lists the contents of the countermeasure work at each slope. The quantity is calculated wherein a typical cross section is applied to the complete section (length).

Table 5.3 List of the Countermeasure Works in N15

Slope	Side	Length	Numbering	Works	Units	Quantity
N15_3	Mountain	L=300m	N-15 No.3-①	Slope Cutting Works	㎡	339,000
			N-15 No.3-②	Framing Works	Sections	3,750
			N-15 No.3-③	Rockbolt Works	Units	750
			N-15 No.3-④	Mortar Spraying Works	㎡	11,100
			N-15 No.3-⑤	Gravity Retaining Wall Works	m	300
			N-15 No.3-⑥	Ground Anchoring Works	Units	3,000
			N-15 No.3-⑦	Drainage Works	m	300
	Valley	L=320m	N-15 No.3-⑧	Drainage Works (Pipe φ75)	Points	2,240
			N-15 No.3-⑨	Revetment Works	㎡	6,720
			N-15 No.3-⑩	Pavement Works $ Soil Improvement Works（Basecourse)	㎡	2,336
			N-15 No.3-⑪	Culvert Works and its Connecting Drainage	㎡	20
	Temporary Works to facilitate to implement above works				set	1
	Total in whole slope					

Slope	Side	Length	Numbering	Works	Units	Quantity
N15_6	Mountain	L=320m	N-15 No.6-①	Slope Cutting Works	㎡	224,000
			N-15 No.6-②	Framing Works	Sections	4,000
			N-15 No.6-③	Mortar Spraying Works	㎡	8,480
			N-15 No.6-④	Gravity Retaining Wall Works	m	320
			N-15 No.6-⑤	Ground Anchoring Works	Units	800
			N-15 No.6-⑥	Rockbolt Works	units	3,200
			N-15 No.6-⑦	Drainage Works	m	320
			N-15 No.6-⑧	Horizontal Dranage Boring to reduce ground water	m	9,000
	Valley	L=380m	N-15 No.6-⑨	Gabion Works	m	320
			N-15 No.6-⑩	Light Weight Banking (e.g. EPS, H=10.0m)	㎡	45,600
			N-15 No.6-⑪	Pavement Works $ Soil Improvement Works（Basecourse)	㎡	2,774
			N-15 No.6-⑫	Culvert Works and its Connecting Drainage	m	20
	Temporary Works to facilitate to implement above works				set	1
	Total in whole slope					

Slope	Side	Length	Numbering	Works	Units	Quantity
N15_8	Mountain	L=330m	N-15 No.8-①	Special Gravity Retaining Wall (Material/Expandable Bags)	m	330
				Special Gravity Retaining Wall (Installation Works)	Sets	1
				Special Gravity Retaining Wall (Transportation Fee)	Sets	1
	Valley	L=300m	N-15 No.8-②	Slope Cutting Works	㎡	27,000
			N-15 No.8-③	Mortar Spraying Works	Section	3,750
			N-15 No.8-④	Rockbolt Works	Units	3,750
			N-15 No.8-⑤	Gabion Works	m	300
			N-15 No.8-⑥	Pavement Works $ Soil Improvement Works（Basecourse)	㎡	2,409
			N-15 No.8-⑦	Culvert Works and its Connecting Drainage	m	300
			N-15 No.8-⑧	Drainage Works	m	300
	Temporary Works to facilitate to implement above works				set	1
	Total in whole slope					

Slope	Side	Length	Numbering	Works	Units	Quantity
N15_9	Mountain	L=130m	N-15 No.9-①	Slope Cutting Works	㎡	87,100
			N-15 No.9-②	Framing Works	Section	3,250
			N-15 No.9-④	Ground Anchoring Works	Units	650
			N-15 No.9-⑤	Rockbolt Works	Units	2,600
			N-15 No.9-⑥	Gravity Retaining Wall Works	m	300
			N-15 No.9-⑦	Drainage Works	m	300
	Valley	L=300m	N-15 No.9-⑧	Pavement Works $ Soil Improvement Works（Basecourse)	㎡	2,190
			N-15 No.9-⑨	Culvert Works and its Connecting Drainage	㎡	20
	Temporary Works to facilitate to implement above works				set	1
	Total in whole slope					

Table 5.4 List of the Countermeasure Works in N75

N75_2	Mountain	L=160m	N-75 No2-①	Slope Cutting Works	m²	55,200
			N-75 No2-②	Framing Works	Section	800
			N-75 No2-③	Mortar Spraying Works	m²	7,040
			N-75 No2-④	Rockbolt Works	Units	800
			N-75 No2-⑤	Gravity Retaining Wall Works	m	160
			N-75 No2-⑥	Drainage Works	m	160
			N-75 No2-⑦	Horizontal Dranage Boring to reduce ground water	m	32,000
	Valley	L=160m	N-75 No2-⑧	Earth Reinforced Works (e.g. Geotextile)	m²	48,000
			N-75 No2-⑨	Drainage Works	m	160
			N-75 No2-⑩	Pavement Works $ Soil Improvement Works (Basecourse)	m²	2,336
			N-75 No2-⑪	Culvert Works and its Connecting Drainage		40
	Temporary Works to facilitate to implement above works					
	Total in whole slope					

Slope	Side	Length	Numbering	Works	Units	Quantity
N75_5	Mountain	L=220m	N-75 No5-①	Slope Cutting Works	m²	48,400
			N-75 No5-②	Comtinous Fivber Spraying Works	m²	10,120
			N-75 No5-③	Drainage Works	m	220
	Valley	L=180m	N-75 No5-④	Light Weight Banking (e.g. EPS, H=16.5m)	m²	18,000
			N-75 No5-⑤	Pavement Works $ Soil Improvement Works (Basecourse)	m²	2,628
			N-75 No5-⑥	Culvert Works and its Connecting Drainage	m	40
	Temporary Works to facilitate to implement above works				set	1
	Total in whole slope					

The concepts for the countermeasure works for each slope are described below.

The slope in N15_3 consisted of a highly weathered and fractured slip surface. With respect to the mountain side, earth-reinforced work (upper part) and ground anchor (main body) are necessary to restrain the moving landmass. The revetment work (conventional method) will be adopted for the valley side. The slope gradient for the mountain side corresponded to 1:0.8 (based on the hard rock and soil as specified by the Guideline of Road Construction: Cutting and Slope Stabilization, Japan Road Association with a height berm of 7 m.

With respect to N15_6, the same countermeasure method as N15_3 will be adopted for the mountain side. The EPS method will be adopted in the valley side. The road pavement will be carried out in conjunction with soil improvements on the road bed.

In N15_8, a gravity-type retaining wall (5 m) is recommended on the mountain side to protect the road from rockfall as a result of the high and steep slope. With respect to the valley side, cutting reinforced work (rockbolt) will be introduced on the valley side to increase slope stability and gabion to protect it from river erosion.

In N15_9, the same method for N15_3 (earth-reinforced) will be adopted to stabilize the slope on the mountain side. The road pavement (with soil improvement) will be implemented on the valley side while the existing retaining wall will be retained.

With respect to N75_2, the re-profiling of the slope to the standard gradient will be implemented on the mountain side while a certain part will be reinforced (i.e., rock bolt and ground anchor). Soil improvements in the road embankment will be implemented to solve the drainage problem (surface water infiltration) that weakens road durability. Embankment-reinforced work utilizing geotextile will be implemented to stabilize the slope on the valley side.

The re-profiling of the slope will be implemented at N75_5 with a standard gradient of 1:0.5 and subsequently covered with a continuous fiber (to protect the slope from weathering and erosion). The EPS will be adopted on the valley side because the spatial distance is limited (steep slope).

The survey team approximately estimated the cost for each slope. The preconditions for the cost estimation are as follows:

1) Essentially, the materials necessary for conventional methods (i.e., retaining wall and gabion) will be procured in Pakistan. The necessary materials for new methods (i.e., earth reinforced work, ground anchor, and lightweight banking (including EPS)) will be procured from Japan.

2) With respect to the geographic conditions, the construction phase was separated into N15 and N75. This implies that the construction supervision is separated into four slopes in N15 and two slopes in N75.

3) The estimated cost for the construction consisted of direct costs (i.e., cost labor expenses, unit price of materials, and machinery expenses of each method) and indirect costs (basic cost estimation for public civil works (Japan building cost estimation).

5.2.3 Pre-condition for financial cooperation

With respect to the pre-condition for financial cooperation, the following two conditions are identified.

1) NHA conducts emergency responses after landslides and establishes a countermeasure zone for restoration. However, they do not adopt pre-countermeasures and do not sufficiently refer to past experiences prior to adopting prevention actions. Thus, a change in NHA policy from emergency response to preparedness is required.

2) The policy of an organization occasionally changes due to changes in NHA Executive Board members. It is necessary that the preparedness policy should be accepted and established by NHA Executive Board.

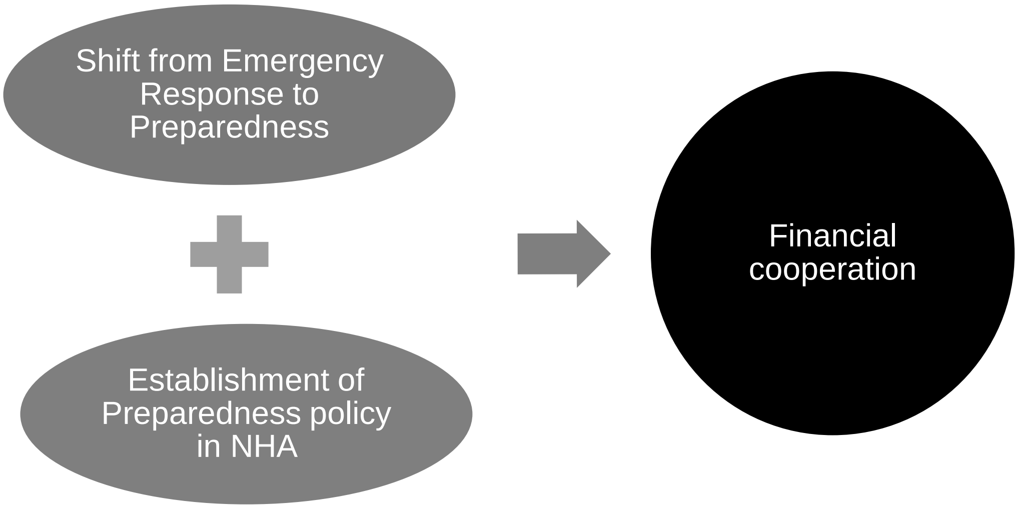


Figure 5.1 Pre-condition for financial cooperation

As discussed above, in the first step, after NHA recognizes the importance of pre-investment for the installment of countermeasures on the selected six slopes, a discussion between JICA and NHA will take place assuming financial cooperation from the government of Japan.

5.3 Capacity development of Road Landslide Countermeasures

In this section, a draft of capacity development (technical cooperation project) for Pakistan is proposed for the four aforementioned issues detailed in section 5.1. Additionally, the pre-conditions for technical cooperation on road landslide countermeasures are summarized.

5.3.1 Pre-condition for technical cooperation

With respect to the pre-condition for technical cooperation, the following three conditions are important.

1) NHA executes emergency response after landslides or establishes a countermeasure zone for restoration However, NHA does not conduct the pre-countermeasure or sufficiently refer to lessons learned from experience prior to adopting prevention action. A strategy shift for the NHA's from emergency response to preparedness is necessary in the future.

2) The policy of an organization occasionally changes due to changes in NHA Executive Board members. It is necessary that the preparedness policy is accepted and established by NHA Executive Board.

3) The authority for decision-making is concentrated on Executive Board members, and it is not possible to rapidly realize decision-making given the absence of members. Based on the lessons learned from the ongoing technical cooperation project with NHA, it is necessary to decentralize decision-making to subordinate members to facilitate quicker decision-making.

5.3.2 Outline of technical cooperation project

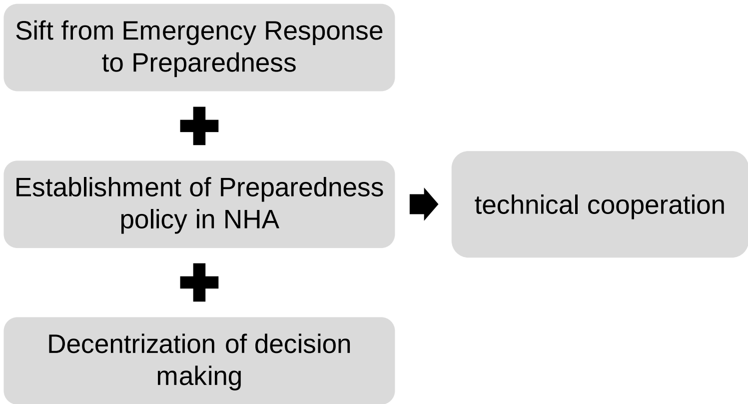


Figure 5.2 Pre-condition for technical cooperation

1. Technical cooperation with respect to investigation, analysis, and monitoring of road landslide disasters

   With respect to the first issue on the "Lack of investigation, analysis, and monitoring technology for landslide disasters", technical assistance including topological and geographic survey / analysis, monitoring, risk assessment, and selection of appropriate countermeasures is desirable. The purposes of the assistance involves improving evaluation technology related to the causes and mechanism of landslide disasters and strengthening the capacity for the selection of appropriate countermeasures. In order to implement effective countermeasures relative to road landslide disasters, it is necessary to initially perform an investigation, analysis, and monitoring of Pakistan's national highway to understand the causes and mechanisms of each disaster such as landslides, slope collapses, rock falls, and debris flows. Thereby, road management authorities should determine the most effective solution for each natural disaster in the future and independently plan the most effective countermeasure methods.

2. Technical cooperation on the creation of a master plan for road landslide countermeasures

With respect to the second issue "A master plan of road landslides countermeasures does not exist", it is desirable to provide technical support via inspecting on road disasters (simplified slope chart) as implemented on Japanese roads and via investigating slope stability and disaster form to create a master plan of road landslide countermeasures. This aids in determining the capacity to elaborate and update a master plan on road landslide disaster management and to establish a system to systematically summarize the history of a disaster. The aim of the project involves supporting the implementation of road disaster inspection via a simplified slope chart and assessing each slope's disaster risk including slope collapse, rock fall, and debris flow, which correspond to typical road landslide disasters in Pakistan. The project also supports the integration of inspection results in the GIS database. Based on the inspection results, hazard assessments, and risk analysis, the project assists NHA in elaborating a master plan to appropriately prioritize implementation of countermeasure works. Henceforth, it is possible for the NHA to implement high-quality slope countermeasures via more effective budget acquisition, planning, and construction management.

3-2. Capacity development on the implementation of structural countermeasures for small to medium-scale landslide disasters

With respect to issue 3.2 "Effective structural countermeasures (infrastructural measures) are not implemented relative to the landslide disasters.", it is necessary to improve disaster management capacity via implementing landslide disaster countermeasures that are technically applicable to Pakistan. The provision of technical assistance aids NHA in selecting sustainable countermeasure works that adopt local resources and construction methods and execute an evidence-based pilot countermeasures work. It is considered that it is possible to prevent a large part of landslide disasters ranging from small to medium-scale disasters via technical guidance from locally applicable countermeasures and existing technology in Pakistan. For example, 1) reinforcement and effective arrangement of retaining walls and gabions; 2) efficient drainage facilitating installations, such as culverts, drainage pipes, and flow path works; and 3) consideration of the gradient of cut earth based on the difference in geology/geological structures. The NHA can execute effective low-cost countermeasures in a short time period via the implementation of the aforementioned "locally applicable" countermeasures.

Large scale landslide disasters are detailed in the previous section (5.2).

4. Capacity development on the preparation of preliminary traffic regulation

With respect to the fourth issue "Technical measures, such as traffic restrictions in advance of landslide disaster, are not established", technical assistance in terms of the preliminary traffic regulation system, early warning system for residents, and introduction of the concept of land utilization is necessary to establish an appropriate preliminary traffic regulation and an early warning system via improving landslide disaster measurement and hazard assessment technologies. The implementation of countermeasures on all road slopes is practically impossible because of limited budget and personnel. Therefore, at high-risk sites, it is necessary to implement countermeasures including preliminary traffic regulation to reduce landslide disasters risk relative to national roads and neighboring residents. The creation of a preliminary traffic regulation system and an early warning system for residents based on landslide disaster risk assessment ensures road traffic safety and reduces economic loss due to sudden traffic closure.

Initially, project 1 is implemented, and this is followed by project 2. Following the completion of the aforementioned projects, projects 3-2 and 4 ensure effective capacity development. It should be noted that projects 3-2 and 4 can be simultaneously implemented.

5.4 Collaboration with other Donors

The possible collaboration of survey outputs with the other donors is described below.

The potential for a collaboration with Landslide Stabilization to Safeguard Civil Population and Infrastructure of Muzaffarabad City (World Bank) is high[58]. The project commenced in October 2017, and the outline of the project is given in Chapter 3.3.2. Figure 5.3 shows a diagram of the possible collaboration with the aforementioned project.

However, coordination among Pakistani organizations is necessary because the counterparts for World Bank projects is forest department of state government, and the project was cancelled because a qualified consultant was not procured.

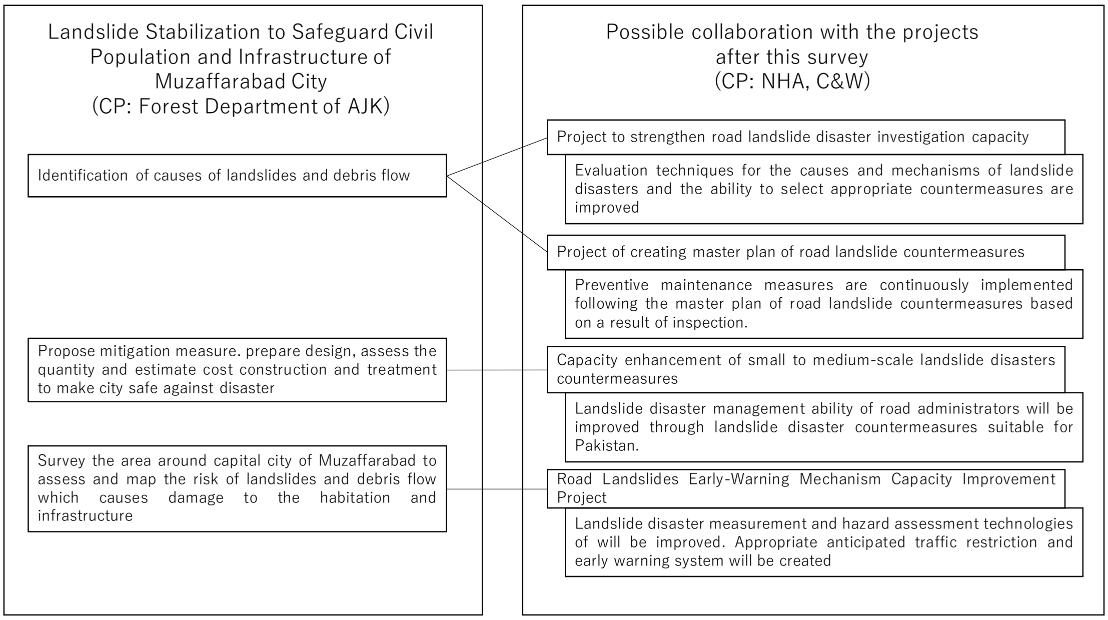


Figure 5.3 Possible Collaboration of the Output of this Survey and Ongoing World Bank's Project
Source: JICA Survey Team

58 Project site of the Landslide Stabilization to Safeguard Civil Population and Infrastructure of Muzaffarabad City is beyond the survey's scope. However, this chapter suggests recommendations for other donor collaboration in the references.

6 Technical Transfer

6.1 Invitation to Japan

6.1.1 Objectives

JICA supported NHA and C&W with financial assistance and technical transfer projects. Currently, JICA has on-going projects in Pakistan including loan assistance, "Khyber Pakhtunkhwa Emergency Road Rehabilitation Project" and the rehabilitation of road infrastructure and technical assistance for the implementation of a bridge management system. Specifically, NHA and C&W are important counterparts in the road transportation sector in Pakistan. On November 2017, JICA invited four NHA personnel including those at the management level to Japan to introduce Japanese technologies that can be utilized in mountainous roads in Pakistan. The NHA and C&W do not implement permanent countermeasures relative to landslides due to the paucity of knowledge on landslide countermeasures in Pakistan. Given the situation, a visit to Japan was conducted to introduce technologies used by Japanese institutions to prevent landslides on roadways. The aim of the visit also included fostering a better relationship between road sector-related agencies in Japan and Pakistan.

The current situation and issues faced by the NHA and C&W are summarized below. Section 6.1.2 describes the contents of Japan visit programs to address the aforementioned issues.

a. Current situation of Landslide countermeasures for NHA and C&W

As mentioned Chapter 2, the NHA and C&W secure a budget for regular maintenance and emergency response of landslide countermeasures. Each regional office can adopt initiatives to construct structures in response to landslide disasters because the budget for landslides is distributed between various regional offices. Small-scale road repairing work is mainly implemented via regional offices.

The cost of large-scale landslide countermeasure works is not included in the annual budget of the regional office, and thus, a regional office is required to send a budget allocation request to the headquarters for the works. The process of sending the request is as follows: an engineer from the regional office submits a report to the department in charge of road maintenance at headquarters. Following the submission of the report to the concerned department, the engineer at the department examines the adequacy of the report.

In case of large-scale or advance landslide countermeasures which can not be managed by regional engineers, NHA headquarter would ask outsource such as structured engineering consultant to draft the report.

b. Capacity Issues faced by NHA and C&W while Implementing Landslide Countermeasures

The current situation in Pakistan is that most landslide countermeasures do not constitute adequately preventive measures and correspond to the results of emergency response after landslides such as the removal of soil mass from an affected road. Additionally, NHA and C&W do not possess sufficient knowledge in terms of preventive acts relative to landslides such as the selection of methodology and review of effectiveness for countermeasures. Thus, engineers from a regional office can only recommend small-scale landslide countermeasures such as masonry retaining walls.

In cases in which large-scale landslide countermeasures is necessary, NHA and C&W typically outsource construction work to consultants. However, NHA and C&W do not possess sufficient capacity to accurately examine the recommendations of a consultant. Thus, they are likely to depend on the capacity of the consultant, and it is difficult to examine the adequacy of countermeasure designs.

6.1.2 Invitation Contents and Site-visits based on the Current Situation and the Issues of Pakistan

The Japan visit consisted of lectures from the Ministry of Land, Infrastructure and Transport (MLIT) in Japan to grasp the concept, effects, and issues of each landslide countermeasure that is adopted by MLIT in Japanese roads. The aim involved ensuring that the headquarters and maintenance unit engineers from the NHA and C&W can evaluate the adequacy of reports related to countermeasure works submitted by consultants in Pakistan.

Furthermore, the participants visited an expressway that is managed by the Central Nippon Expressway Company (NEXCO). Specifically, NEXCO is in charge of conducting emergency response/countermeasures after landslide disasters although they outsource the design and implementation of permanent countermeasures to consultants. Therefore, the participants learned how to respond in emergency situations and how to implement permanent countermeasures by visiting and observing the manner in which NEXCO maintains its expressway.

Additionally, the participants learned the relationship between contractors and consultants via a lecture by the National Research and Development Agency. Furthermore, Japanese companies conducted presentations to introduce their landslide countermeasure technologies. The programs were conducted to determine the challenges faced by Japan and Pakistan and to detail all know-how and Japanese technology that are applicable in Pakistan.

The details of the invitation schedule are listed in Table 6.1.

Table 6.1 Invitation Schedule

Days	Date		Movement	Lecturer	Invitation Program Contents
1	2018 /6/30	Sat	Islamabad -Bangkok		Flight（TG350 23:20-06:25）
2	7/1	Sun	Bangkok-Tokyo		Flight（TG676 07:35-15:45）
3	7/2	Mon	Tokyo	【Kokusai Kogyo Co., Ltd Headquarter】 【NEXCO Research Institution】	AM：Orientation (Overview of the training) PM：Lecture on Countermeasure Works carried out by NEXCO (Anchoring Works, Bio-Engineering etc.)
4	7/3	Tue	Tokyo	【NEXCO Nakanihon】	On-site visit at Makinohara IC (the site where road disasters happen after the earthquakes) (*if possible, the person in charge at the time of the disasters, will explain the emergency response and the implementation of the permanent countermeasures)
5	7/4	Wed	Tokyo Saitama (Next to Tokyo)	【MLIT,　Kanto Regional Development Bureau, Road Division】	AM：Structure of MLIT, Countermeasures for Road Disaster, etc. (includes key points on road construction, comparison between temporary countermeasures and permanent countermeasure for landslides) PM：Structure of Kanto Regional Development Bureau, Emergency response system for road disasters, visit to road information monitoring room, etc.
6	7/5	Thu	Ibaraki Prefecture Tsukuba City	【Public Works Research Institute (PWRI) Geology Research Team】 【National Research Institute for Earth Science and Disaster Resilience】	AM：Landslide disaster and countermeasures in Japan, inspection of road disasters, road disaster hazard map, etc. AM：Research of prevention methods for road disasters PM：Landslide Geospatial Information System Map, Tour of mass-precipitation meters
7	7/6	Fri	Tokyo	【JICA Tokyo Office(@Kojimachi)】 【Pakistan Embassy】	AM: Discussion with JICA about the Project PM: Meeting with the Pakistan Ambassador
8	7/7	Sat	Tokyo		Day off
9	7/8	Sun	Tokyo		Day off
10	7/9	Mon	Tokyo	【Protec Engineering/Nittoc Construction/Tokyo Rope】	AM: Countermeasure Works for Road Disaster by Japanese companies PM: Countermeasure Works for Road Disaster by Japanese companies
11	7/10	Tue	Gunma	【MLIT Kanto Region Yanba Dam /Nittoc Construction】	On-site visit, Yanba Dam Osawa District(the construction sites of MLIT, works carried out by Nittoc Construction)
12	7/11	Wed	Tokyo-Bangkok-Islamabad		Flight（TG643 12:00-16:30） Flight（TG349 19:00-22:10）

Source: JICA Survey Team

6.1.3 Schedule of the Invitation to Japan

With respect to the schedule of the visit to Japan, the following three factors were considered, namely the Ramadan period lasted until late June, an NHA training was scheduled by ADB from September to October, and NHA and C&W were busy at the end of June since it corresponded to the end of the fiscal year. Therefore, the participants were requested to schedule the visit to Japan after the last week of June, and thus the visit took place from 30th (Sat) June to 11th (Thu) July 2018.

6.1.4 Participants for the Invitation to Japan

Given the aforementioned current situation and issues, 10 participants from the NHA and RAMD (i.e., headquarters and the regional offices, and other departments related to landslide countermeasures) visited Japan. A participant was a Member of the Engineer and Coordination Department with the authority to approve road maintenance projects on N-75, which corresponds to an important road that connects Islamabad and Murree and is located in a landslide-prone area. It was crucial for the Member to understand the importance of implementing permanent countermeasures as opposed to implementing emergency countermeasures after the occurrence of landslides.

Additionally, C&W has an on-going project funded by JICA: “Khyber Pakhtunkhwa Emergency Rural Road Rehabilitation Project.” The participants from C&W were in charge of the project, and thus the visit to Japan aided in improving project implementation via learning the current situations related to landslide countermeasures in Japan.

The details of the participants are listed in Table 6.2.

Table 6.2 List of the Participants

No.	Organization	Title	Name
1	NHA	Member (Engg-Coord)	Altamash Khan
2	NHA	GM (Maintenance), Muzaffarabad	Jamal Abdul Nasir*
3	NHA	Director (P&CA)	Ijaz Ahmed
4	NHA	Deputy Director (Pavement Design)	Tariq Riaz
5	NHA	Deputy Director (RAMS)	Muhammad Asif Azam
6	NHA	Deputy Director (Lowari Tunnel Project)	Babar Khan
7	NHA	Deputy Director (Maintenance) Murree	Khanzada
8	C&W KP	Secretary	Shahab Khattak
9	C&W KP	Deputy Director	Muhammad Ayub
10	C&W KP	Deputy Director	Waqas Ali Shah

*Jamal Abdul Nasir was absent

Source: JICA Survey Team

6.2 Seminar

A "JICA Landslide Seminar, Data Collection Survey on Landslide Measures" was conducted on Friday (April 20th, 2018) at NHA Headquarters Conference Hall in Islamabad. It included 119 participants (100 individuals from the Pakistani side and 19 people from the Japanese side). Specifically, the survey team conducted presentations on the outline, objectives, progress, and prospects of the survey, and five private Japanese companies conducted presentations on road landslide countermeasure technologies in Japan. Additionally, the survey team conducted a presentation detailing Japanese experience in road landslide management. The agenda of the seminar is specified in the table below.

Table 6.3 Agenda of the "JICA Landslide Seminar, Data Collection Survey on Landslide Measures"

Name of the event	JICA Landslide Seminar, Data Collection Survey on Landslide Measures
Date	20th of April, 2018, 10:00–15:40
Venue	NHA HQ, Conference hall, Islamabad
Participants	Pakistani side: NHA HQ staff and regional staff, C&W staff, NDMA staff, University professors and students, Consultants, etc. Japanese side: JICA staff, Construction companies, Trading companies, Survey team
Agenda	
Contents	Presenter
0. Registration	-
1. Opening speech	NHA Chairman
2. Opening speech	JICA Pakistan Office Representative
3. Explanation of The Survey and its objectives	Deputy survey team leader
4. Coffee break	-
5. Presentation of Japanese Road Disaster Countermeasure Technologies 1	Tobishima Corporation Nittoc Construction Taisei Corporation
6. Flow for enactment of landslide countermeasures	NDMA Expert
7. Presentation of Japanese Road Disaster Countermeasure Technologies 2	Koken Boring Machine
8. Prayers and lunch break	-
9. Presentation of Japanese Road Disaster Countermeasure Technologies 3	Kokusai Kogyo
10. Lessons learned from Japanese Road Landslide Management	Deputy survey team leader
11. Methodology, progress and prospects of The Survey	Survey team road disaster expert
12. Q&A	-

Source: JICA Survey Team

The aggregate results of the questionnaire as elicited from seminar participants are detailed in table 7.4.

Table 6.4 Aggregate Results of the Questionnaire in the "JICA Landslide Seminar, Data Collection Survey on Landslide Measures"

JICA Landslide Seminar Questionnaire

Question	Answer			
	Not much	More or less	A lot	Completely
1. Introduction				
Did you understand the outline of the survey?	0	5	7	5
Did you understand the purpose of the survey?		2	10	5
2. Japanese companies				
Did you understand the presented road disaster preventive measures in Japan?		3	10	4
Do you think there should be more investment in road disaster preventive measures in Pakistan?		1	7	9
Comments	・Rockbolting, soil nailing, and seeding were very interesting ・More detailed techinical contents should be discussed ・Japanese disaster management was interesting ・The methodology for the survey was interesting ・It is important to choose countermeasures depending on each slope			
3. Survey summary				
Did you understand the survey's methodology for site survey?	1	5	10	1
Do you think the technical know-how of how to assess road disasters should be enhanced in Pakistan?		1	8	8
Do you think the technical know-how for designing and constructing countermeasure works should be enhanced in Pakistan?			10	7
4. Others				
Do you think assisting to this seminar was useful to increase your knowledge on road landslide management?	1	2	9	5
Comments	・Presentation about cost-effectiveness would be interesting ・Landslide measures should be furtherly discussed in Pakistan ・Want to know more about specific landslide countermeasure cases ・More events like this should be carried out ・Japanese countermeasures should be introduced to Pakistan ・The contents of the seminar are crucial in Pakistan ・The seminar should have been longer ・Countermeasures adapted to Pakistani economic situation should be developed			

Source: JICA Survey Team

The main comments are shown in Table 6.4. Positive comments on the contents of the seminar were also given verbally by high-ranking officials from the NHA.

Figure 6.1 Presentation about Japanese Road Disaster Countermeasure Technologies

Source: JICA Survey Team

Figure 6.2 Opening speech from NHA Chairman and the Representative of the JICA Pakistan Office

Source: JICA Survey Team

To ensure a better understanding of Japanese seminar participants from private companies on roads and landslides in Pakistani national highways, a site inspection along N-75 will be conducted on the day before the seminar (Thursday, April 19th, 2018) by the survey team.

Figure 6.3 Site Inspection along N-75 with the Seminar Participants from Japanese Companies

Source: JICA Survey Team

6.3 Technical Transfer of Slope Chart

The NHA requested the technical transfer to create a slope chart to monitor actual slopes along N-75 and to understand actual tasks via completion of the slope chart. Based on a request by NHA, on-site training (i.e., basic introduction of the technical transfer on the slope chart) was implemented at few slopes sites (including slopes where countermeasures were implemented) between Islamabad and Murree (N75),November 8th, 2017. Specifically, the survey team taught NHA staff the main fundamental points in the Slope Carte from the aspects of topographic and geological observation. These points are ranged in the aspects such as how to observe the slope scale, slope inclination and slope composite materials for example (soil, and rock), how to identify the slip surface and how to detect the slope seepage.

Figure 6.4 Situation of Pilot OJT

Source: JICA Survey Team

In addition to the training mentioned above, OJT with the C/P was conducted at candidate slopes in the long list along N15, N35, and N75 on December 2017. The OJT along N-15 focused on the characteristics of slope failures at a steep mountain (3,000–4000 m) and especially on geomorphology (i.e., method to determine slope area from the area of a colluvium).

Figure 6.5 OJT toward the C/P (Left) and N75_2 (Right)

Source: JICA Survey Team