ROAD GEOHAZARD RISK MANAGEMENT

APPENDIX A: TERMS OF REFERENCE
APPENDIX B: OPERATIONS MANUAL

GFDRR
Global Facility for Disaster Reduction and Recovery

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ROAD GEOHAZARD RISK MANAGEMENT

APPENDIX A: TERMS OF REFERENCE

INSTRUCTIONS TO USERS OF THESE TORS

Items in **blue** are instructions for where the user is to insert the relevant information to make the ToR complete.

Items in **yellow** are instructions for where users may wish to revise the wording in the ToR to reflect their particular needs.

APPENDIX A.1

Terms of Reference 1 (ToR 1)

INSTITUTIONAL CAPACITY REVIEW AND TARGET SETTING

1 BACKGROUND

This box is to be deleted once ToR is completed by the road authority.

Provide a paragraph or two on the background to this ToR. For example, is it part of a World Bank-funded technical assistance (TA) project or similar?

This Terms of Reference (ToR) is for the completion of an Institutional Capacity Review for road geohazards. It is intended to align with the methodologies and approaches defined in the "Road Geohazard Risk Management Handbook."

This ToR covers the <<Insert Road Authority Name>> (the "Road Authority") that is responsible for the development, maintenance, and operation of the <<Insert road hierarchy>> road network within <<Insert country and/or state name>>. The ToR covers all areas of operation within the Road Authority that reasonably affect road geohazard risk management. Where aspects of service delivery related to geohazard risk management are outsourced to the private sector (consultants or contractors), then this Institutional Capacity Review should cover the contractual terms of such arrangements along with any information on how well the contractual requirements are being met.

The Road Authority notes the following observations regarding its own management of road geohazard risks and the associated risks that the road network is exposed to:

<<Replace following bullet points with relevant comments on the current status>>

- Government's role and stance regarding road geohazard risk management
- Is the work delivered using in-house resources, or is some outsourced to private sector consultants or contractors?
- Current status of road sector and road network development: for instance, well-developed road network, basic infrastructure
- Condition or characteristics of natural disasters: for instance, wide-scale flooding or mountain landslides
- Particular risk factors: for instance, climate or topography, that may affect the frequency or severity of geohazard events
- Examples of road damage events by geohazards: for instance, in 2016 there was a major flood that xxx
- Needs for road geohazard risk management

2 OBJECTIVES

The Institutional Capacity Review and target setting are intended to determine the Road Authority's existing capacity to implement road geohazard risk management, assess the gaps, and recommend ways or target to strengthen capacity.

The objectives of the consulting services are as follows:

- To formally assess the capability of the Road Authority (and any entity contracted to provide parts of the geohazard response) across the full range of competencies required to successfully deliver the outputs specified in the Road Geohazard Risk Management Handbook
- To set appropriate target competencies for all geohazard risk management activities
- To identify and recommend ways to address any deficiencies between the assessed and target competencies
- To prepare a prioritized and costed improvement plan for action by the relevant transport sector participants.

3 SCOPE OF WORK

3.1 Understanding of Road Geohazard Risk Management Practices

This first stage is about developing an understanding of the geohazard risk context that the road sector is operating within. Furthermore, this stage in the process is to ascertain who (what part of the Road Authority) is responsible for the various aspects of the geohazard risk management process. The information reviewed at this stage will include

- Review of the Road Authority's organizational structure to ascertain the relevant roles and responsibilities pertaining to geohazard risk management;
- Review of any contractual arrangements with the private sector relevant to geohazard risk management;
- Desktop-based information and data collection survey of the geohazard risk characteristics that the road network is exposed to;
- Desktop-based information and data collection survey and description of the road sector's current status (for example, road networks and development status of roads);
- Review of previous studies on road geohazard events; and
- Summary of the characteristics of road geohazards that are present on the network.

The findings of this stage of the assignment shall either be summarized in a short stand-alone report or prepared as a chapter for inclusion in the Final Report. The report shall be submitted to the Client for review and confirmation that the understanding gained is correct.

3.2 Assessment of Current Capability

The Consultant is to use the checklists included in Annex A.1.1 as Attachment 1 (also available as a Microsoft Excel file) to guide the assessment of the current capability. The Consultant may add additional details or questions to the checklist as they deem appropriate. The findings of this stage of the assignment shall be through submission of the completed checklists. The checklists shall be submitted to the Client for review.

3.3 Target Setting and Improvement Actions

Having completed the assessment of current geohazard risk management capability, the Consultant is to define an appropriate level of competency for each of the assessed items. These targets should reflect the level of geohazard exposure on the transport network. Note that for transport networks with very low exposure to geohazard risks, the absence of specific functions may not be considered worthy of action.

For each item where the target capability is above the current assessed capability, the Consultant is to define specific action(s) to close the gap. The actions should be classified as High, Medium, or Low priority—recognizing that there is seldom capacity to address every deficiency at once and that some actions will be more critical than others.

The findings of this stage of the assignment shall be expressed through

- A statement of the target capability for each assessed item; and
- A prioritized improvement action list, with each action linked to the target(s) that it will impact.

4 DELIVERABLES

Each deliverable shall be provided first as a draft, and after Client's feedback will be submitted in final form. Unless otherwise directed, the acceptance of each deliverable by the Client shall be treated as a contract hold point. The Client may request a workshop on any of the deliverables once they have had time to review the Draft Final Report.

4.1 Inception Report

The Consultant shall understand the background and the objective of this work and describe as such in an Inception Report (IR). The IR shall as a minimum confirm contents of the Work (tasks), prepare a work plan, and confirm the timings of any required interviews or meetings with the Road Authority staff (and private sector participants if determined relevant) in the completion of the assignment. The IR shall be submitted to the Client for approval.

4.2 Progress Reports

The Consultant shall prepare two progress reports:

(I) Understanding of Road Geohazard Practices summarizing the current approach to road geohazard risk management practices. The purpose of this report is to ensure that prior to the completion of the formal assessment, the overall approach to road geohazard management is appropriately understood.

(II) Assessment of Current Practices, which shall include the assessment process and the current status of geohazard risk management. This report includes the completed assessment tables.

4.3 Final Report

The Consultant shall prepare the Final Report, which shall include all the results of the tasks described herein.

The Consultant shall revise and update the contents of the Draft Final Report by considering comments from the Client. All the documents on the risk evaluation shall be finalized and included in the Final Report. Collected data and output maps must be submitted to the Client upon completion of the project.

5 SCHEDULE

[Note that the duration of this ToR will be related to the size of the Road Authority. For small Road Authorities, the inputs may take as little as one week, while the inputs for large Road Authorities with many different departments may take several months to complete (including time for Client's review and finalization of reporting). As with the comments on the skills and experience required, the Client will need to ensure that the inputs are appropriate for the scope of works.]

All tasks shall be completed within 150 working days after contract effectivity, according to the schedule outlined below. In addition, meetings, seminars, or workshops shall be planned as necessary.

- Submission of Inception Report: within 15 days after contract effectivity. The Consultant shall prepare the IR, which shall include the table of contents, methodology, and schedule of the country capacity review. Copies of the IR shall be delivered to the Client. The Consultant shall orally explain the IR's contents in a presentation upon delivery of the IR to the Client.
- Submission of Report (I): Understanding of Road Geohazard Practices: within 45 days after contract effectivity. The Consultant shall prepare and submit Report (I).
- Submission of Report (II): Assessment of Current Practices: within 100 days after contract effectivity. The Consultant shall prepare and submit the Report (II), which should describe the assessment process and the current status of geohazard risk management.
- Submission of Draft Final Report: within 120 days after contract effectivity. The Consultant shall prepare and submit a Draft Final Report that includes all the results of the Work. The Draft Final Report shall contain the outputs from Reports (I) and (II) above, along with the results of the target setting and improvement action tasks. The Consultant shall orally explain the Draft Final Report's contents in a presentation upon delivery of the Draft Final Report to the Client. The Consultant shall collect comments on the Draft Final Report from the Client.
- Submission of Final Report: within 150 days after contract effectivity. The Consultant shall prepare and submit the Final Report, which shall contain the required revisions to the contents of the Draft Final Report based on the comments from the Client. The Consultant shall submit all the deliverables, including the Final Report, to the Client.

6 PROFESSIONAL SKILLS AND EXPERIENCE REQUIRED

The Consultant's team will include qualified personnel with extensive experience in organizational capability assessment. The consulting firm shall have sufficient qualified personnel and resources, including international technical expertise and advisers, to provide all necessary professional, technical, and expert services as required to accomplish all the services described above within the prescribed time.

The Consultant shall assemble a team for undertaking the scope of work and tasks described above. In responding to the ToR, consultancy organizations will provide curricula vitae, a description of roles and responsibilities, and a written statement of exclusivity and availability of key experts who will be working on the project.

Consulting firms may form joint ventures or associations with other consulting firms to enhance their capabilities, strengthen the technical responsiveness of their proposals, make available bigger pools of experts, and enhance the value and quality of their services. The following key personnel (whose experience and responsibilities are briefly described) will be considered in the evaluation of the technical proposals. Other expertise as required for the services to be rendered should be included as necessary and to reflect the Consultant's responsiveness to the ToR.

The Client will need to review these following estimated inputs in the context of the extent of the Road Authority to be assessed.

It is estimated that this project will require three person-months from the team and will be completed within a period of five months. A list of suggested key personnel to be deployed by the Consultant, with appropriate minimum person-months of each as per Client's assessment, is shown in Table A.1.1. However, the Consultant can make their own assessment of the required composition and person-months for the key personnel and the phasing of their mobilization. The adequacy of the proposed composition will be assessed in the context of the proposal.

Table A.1.1 Estimated Input of Key Professional Staff

NO.	POSITION	PERSON-MONTHS
1	Team leader or lead assessor	2
2	Geotechnical specialist	0.5
3	Hydraulic specialist	0.5
4	Civil engineer	0.5
Total estimated key staff person-months		3.5

The person nominated for the team leader or lead assessor role may also be nominated for any of the other roles.

Minimum qualifications and experience of key professional staff are summarized in Tables A.1.2–A.1.5. However, the Consultant may propose an effective team considered to be the most suitable for carrying out the project. The technical proposal must outline why the proposed composition of the team is considered capable and most suitable.

Table A.1.2 Qualifications and Skills of Team Leader or Lead Assessor

Qualification and skills	Minimum of a master's degree in civil or highway engineering, computer science, information and communication technology (ITC), or a related topic, or equivalent professional experience of at least 15 years Fluency in English <<and Add other languages as required>> language, both written and oral
General professional experience	At least 10 years of professional engineering experience
Specific professional experience	• Proven leadership and people management skills, including the ability to establish and maintain effective working relationships in an international multicultural working environment • Experience regarding work activities in transitioning or low- and middle-income countries • Experience in providing training or knowledge transfer to Client staff preferred • Minimum of five years' experience in conducting capability assessments of large organizations • Knowledge in geohazard risk management • Preferably having assessed two road authorities for organizational performance (may be in a field other than geohazard management, such as quality assurance, asset management, or the like)
Key responsibilities	Lead all aspects of the assessment, including surveys, workshops, and reporting Undertake all Client liaison activities

Table A.1.3 Qualifications and Skills of Geotechnical Specialists

Qualifications and skills	Minimum of a master's degree in civil, road, or geotechnical engineering or a related topic, or equivalent professional experience of at least 10 years Fluency in English language, both written and oral
General professional experience	Expertise and experience in activities relating to life-cycle management of geotechnical assets
Specific professional experience	• At least 10 years of professional experience in areas relevant to this project • Understanding of landslide hazards and failure mechanisms of geotechnical assets • Understanding of risk-based evaluation methodologies preferred
Key responsibilities	Lead all geotechnical aspects of the assignment: develop land movement scenarios, estimate consequences, and so on

Table A.1.4 Qualifications and Skills of Hydraulic Specialist

Qualifications and skills	Minimum of a master's degree in civil, road, or geotechnical engineering, or related topic, or equivalent professional experience of at least 10 years Fluency in English language, both written and oral
General professional experience	Expertise and experience in activities relating to life-cycle management of geotechnical assets
Specific professional experience	• At least 10 years of professional experience in areas relevant to this project • Understanding of hydraulic modeling of catchments, climate modeling, and impact on road infrastructure • Understanding of risk-based evaluation methodologies preferred
Key responsibilities	Lead all geotechnical aspects of the assignment: develop hydraulic scenarios, estimate consequences, and so on

Table A.1.5 Qualifications and Skills of Civil Engineer

Qualifications and skills	Minimum of a master's degree in civil, road, or geotechnical engineering or a related topic, or equivalent professional experience of at least 10 years Fluency in English language, both written and oral
General professional experience	Expertise and experience in estimating the costs of highway works
Specific professional experience	• At least 10 years of professional experience in areas relevant to this project • Understanding of road damage caused by geohazards • Understanding of risk-based evaluation methodologies preferred
Key responsibilities	Develop cost estimates of damages to the road infrastructure for the scenarios under analysis

7 ATTACHMENT 1: CHECKLISTS FOR INSTITUTIONAL CAPACITY REVIEW

No.	Question	Check items
PART II: INSTITUTIONAL CAPACITY AND COORDINATION		
1	Is there a clear institutional framework for management of road geohazards?	Clear and documented framework—either stand-alone or integrated with overall road authority management documents
2	Have laws and/or regulations been formulated?	Laws of disaster risk management (or geohazard risk management)
3	Have technical standards, guidelines, or manuals been prepared?	Technical standards, guidelines, or manuals for disaster risk management (or geohazard risk management)
4	Is an overall plan or strategy in place to address road geohazards?	Documented and well-understood plan or strategy in place
5	Are roles and responsibilities clearly understood?	Job descriptions for various roles, including geohazard responsibilities and appropriate expertise, in place
6	Where some roles and responsibilities have been contracted out, do the contractual arrangements clearly specify their geohazard duties?	Contract documents for any external consultants or contractors involved in any aspect of the geohazard risk management activities

Answer options **Status (1–4)** **Choose one of the answer options from the left column**	**Effectiveness or appropriateness** **0. No** **1. Low** **2. Moderate** **3. High**	**Description on the current status** *Summarize current status, effectiveness, problems, and so on.* *Add comments if necessary.*	**Reference materials or name of respondent, position, and agency** *Author (year): Title of reference* *or* *Name, position, agency*
0. Not yet started 1. Formulating 2. Formulated 3. Utilizing partially 4. Utilizing fully			
0. Not yet started 1. Formulating 2. Formulated 3. Enforcing partially 4. Enforcing fully			
0. Not yet started 1. Preparing 2. Prepared 3. Utilizing partially 4. Utilizing fully			
0. Not yet started 1. Preparing 2. Prepared 3. Utilizing partially 4. Utilizing fully			
0. Not yet started 1. Preparing job descriptions 2. Roles under preparation 3. Roles defined but often not appropriately staffed 4. Roles defined and appropriately staffed			
0. Not yet started 1. Vague reference to geohazard duties 2. Clearly defined but not well understood duties 3. Clearly defined and well understood, but contractual barriers remain 4. Contractual arrangements do not pose any negative impact on the delivery of geohazard risk management			

No.	Question	Check items	
7	Is a funding mechanism in place to proactively manage geohazards?	This pertains to funding for the management of geohazards and not the physical works to repair or mitigate them.	
8	Is funding in place to undertake proactive repairs to stop geohazard risks from occurring?	This pertains to installing measures (often engineering) ahead of a geotechnical failure. How long would it take, with current annual funding, to proactively address all known high- and medium-risk sites?	
9	Is funding in place to undertake reactive repairs after geohazard risks failed?	This pertains to funding for the removal of materials and repairs at a single site to restore network operations.	
10	Is funding in place in the event of a major natural disaster event?	This pertains to funding following areawide natural disasters that may have geotechnical failures.	

Answer options **Status (1–4)** **Choose one of the answer options from the left column**	**Effectiveness or appropriateness** **0. No** **1. Low** **2. Moderate** **3. High**	**Description on the current status** *Summarize current status, effectiveness, problems, and so on.* *Add comments if necessary.*	**Reference materials or name of respondent, position, and agency** *Author (year): Title of reference* *or* *Name, position, agency*
0. No 1. Limited to investigating areas of previous failure 2. Funding available to manage some high-risk sites 3. Funding available to proactively manage all high-risk sites 4. Sufficient funds to manage all aspects of geohazards			
0. No funding available 1. > 20 years 2. > 10 years 3. < 10 years 4. All sites have been addressed			
0. No base funding, requires budget reallocation 1. Funding in place for key routes only and only when traffic operations are impeded 2. Funding in place for all key routes 3. Funding in place for all reactive repairs, but authorization to spend is slow 4. Funding in place for all reactive repairs with quick authorization to undertake works			
0. No fund exists 1. Fund exists but only likely to cover 25% of the cost of a major disaster 2. Fund exists but only likely to cover 50% of the cost of a major disaster 3. Fund exists but only likely to cover 75% of the cost of a major disaster 4. Fund exists and considered appropriately sized to cover a major natural disaster			

No.	Question	Check items	
11	Is the overall arrangement effective?	When considering the overall arrangement, is it working effectively, or is it disjointed and ineffective?	
12	Is sufficient technical expertise available for institutional capacity activities?	This considers both the capability and capacity of those involved, including both Road Authority staff and those outside the Road Authority who play key roles.	
PART III: SYSTEMS PLANNING			
13	Is a program in place to identify risks on the existing road network?	Register of risks is available for inspection, with evidence of regular checking and updating of contents.	
14	Is GIS used in the management of risks on the network?	GIS is a key technology to store and manage data pertain-ing to geohazard risk management.	
15	Is a methodology in place to prioritize sites for proactive measures?	Is a documented prioritization method in place?	

Answer options Status (1–4) Choose one of the answer options from the left column	Effectiveness or appropriateness 0. No 1. Low 2. Moderate 3. High		Description on the current status *Summarize current status, effectiveness, problems, and so on. Add comments if necessary.*	Reference materials or name of respondent, position, and agency *Author (year): Title of reference or Name, position, agency*
0. Ineffective arrangements in place 1. Arrangements rely on personal relationships rather than document methods 2. Key processes work okay, but obvious gaps exist 3. Overall processes and arrangements are good but not delivering effectively 4. Overall processes are effective, without obvious weaknesses				
0.No 1. Okay for simple situations 2. Limited ability to investigate cause of failures 3. Sufficient expertise for most situations 4. Technical expertise is not a constraint				
0. Never done 1. Planning 2. Planned 3. Conducting partially 4. Conducted fully				
0. No 1. Just to plot geohazard sites 2. Only contains data relating to the road authority 3. Contains all necessary data, but limited analysis undertaken 4. Fully used in all aspects of risk management, including analysis				
0. No 1. Just on AADT or road hierarchy 2. Considers wider social services (hospitals, schools, etc.) accessed via the route 3. Based on network-level analysis of criticality of road links 4. Considers both probability and consequence of failure				

No.	Question	Check items	
16	Is there a methodology for the selection of optimal solutions at a project level?	How is the solution selected for a given geohazard risk site?	
17	Is sufficient technical expertise available for systems planning activities?	This considers both the capability and capacity of those involved, including both Road Authority staff and those outside the Road Authority who play key roles.	
PART IV: ENGINEERING AND DESIGN			
18	How are solutions designed?	Where engineered solutions such as retaining walls are to be constructed, what is the basis of the design?	
19	Is sufficient technical expertise available for engineering and design activities?	This considers both the capability and capacity of those involved, including both Road Authority staff and those outside the Road Authority who play key roles.	

Answer options Status (1–4) Choose one of the answer options from the left column	Effectiveness or appropriateness 0. No 1. Low 2. Moderate 3. High	Description on the current status *Summarize current status, effectiveness, problems, and so on.* *Add comments if necessary.*	Reference materials or name of respondent, position, and agency *Author (year): Title of reference* *or* *Name, position, agency*
0. No documented methodology 1. Standard designs or solutions applied 2. Lowest initial cost 3. Full life-cycle costing of a range of options 4. Full life-cycle costing of a range of options and considering both Road Authority and road user impacts			
0. No 1. Okay for simple situations 2. Limited ability to investigate cause of failures 3. Sufficient expertise for most situations 4. Technical expertise is not a constraint			
0. No design, just try something on-site 1. Use standard design solutions 2. Some basic investigations are undertaken, but modeling of complex failure modes is not undertaken 3. Based on modeling and analysis of a small number of options 4. Based on extensive modeling and analysis to yield "optimized" design			
0. No 1. Okay for simple situations 2. Limited ability to investigate cause of failures 3. Sufficient expertise for most situations 4. Technical expertise is not a constraint			

No.	Question	Check items
PART V: OPERATIONS AND MAINTENANCE		
20	Is a program for road disaster awareness in place?	Does the Road Authority actively engage with road users and stakeholders to raise awareness of geohazards?
21	Is land-use control in place to minimize geohazard risks?	Does the Road Authority engage with landowners and government bodies to control land use that could negatively affect geohazard locations?
22	How is geohazard information communicated to road users?	What different tools and technologies are used to communicate updates to road users about geohazard events?
23	Are previously engineered solutions inspected and maintained according to the recommended schedules?	Engineered solutions will typically have recommended inspection and routine maintenance regimes with them. Are these being followed through on?
24	Does the asset management framework within the Road Authority specifically consider geohazards?	Ideally, geohazard risk management should form part of the overarching asset management activities.
25	Is sufficient technical expertise available for operations and maintenance activities?	This considers both the capability and capacity of those involved, including both Road Authority staff and those outside the Road Authority who play key roles.

Answer options Status (1–4) Choose one of the answer options from the left column	Effectiveness or appropriateness 0. No 1. Low 2. Moderate 3. High	Description on the current status *Summarize current status, effectiveness, problems, and so on.* *Add comments if necessary.*	Reference materials or name of respondent, position, and agency *Author (year): Title of reference* *or* *Name, position, agency*
0. Never done 1. Planning 2. Planned 3. Conducting partially 4. Conducted fully			
0. Never done 1. Planning 2. Planned 3. Conducting partially 4. Conducted fully			
0. Never done 1. Road Authority website 2. ITS signage in the local proximity of the geohazard location 3. ITS signage across the network to permit rerouting of trips by road users 4. Full use of social media, SMS, website, ITS signage, and so on			
0. Never done 1. Planning 2. Planned 3. Conducting partially 4. Conducted fully			
0. No asset management framework 1. Planning 2. Planned 3. Parallel but not integrated processes 4. Full integration of geohazard management into the asset management framework			
0. No 1. Okay for simple situations 2. Limited ability to investigate cause of failures 3. Sufficient expertise for most situations 4. Technical expertise is not a constraint			

No.	Question	Check items
PART VI: CONTINGENCY PROGRAMMING		
26	Is an emergency response plan in place?	Is a documented emergency response plan in place that covers all stakeholders?
27	Are emergency inspection arrangements in place?	In the event of an emergency, do all necessary parties know what to inspect and whom to report to, and do they have authority to close roads if unsafe situations identified?
28	Do recovery measures include the concept of “build back better”?	After an event, is the focus on rebuilding as it was before, or are enhancements included to lower the risk of future events?
29	Do test runs of the preparedness plans occur?	Is there regular testing of the plans and procedures for responding to emergency events?
30	Is sufficient technical expertise available for contingency planning activities?	This considers both the capability and capacity of those involved, including both road authority staff and those outside the road authority that play key roles.

Note: Checklist also available as a Microsoft Excel file. AADT = annual average daily traffic. GIS = geographic information system(s). ITS = intelligent transportation system. SMS = short message service (texts).

Answer options **Status (1–4)** **Choose one of the answer options from the left column**	**Effectiveness or appropriateness** **0. No** **1. Low** **2. Moderate** **3. High**	**Description on the current status** *Summarize current status, effectiveness, problems, and so on.* *Add comments if necessary.*	**Reference materials or name of respondent, position, and agency** *Author (year): Title of reference* *or* *Name, position, agency*
0. Never done 1. Planning 2. Just covers the Road Authority 3. Fully documented, covering all relevant stakeholders 4. Fully documented and followed in event of an emergency			
0. Never done 1. Planning 2. Documented but not yet consis-tently followed 3. Inspections occur, but no authority to act on what is found 4. Fully documented and followed in event of an emergency			
0. Never done 1. Planning to introduce 2. Only for high-priority routes 3. Only for high- and medium-priority routes 4. Always done			
0. Never done 1. Planning to introduce 2. Only for deemed 'key' risks 3. For all risks, but not regular 4. Regular complete testing			
0. No 1. Okay for simple situations 2. Limited ability to investigate cause of failures 3. Sufficient expertise for most situ-ations 4. Technical expertise is not a con-straint			

APPENDIX A.2

Terms of Reference 2 (ToR 2)

RISK EVALUATION AND RISK MANAGEMENT PLANNING

This box is to be deleted once ToR is completed by the road authority.

Provide a paragraph or two on the background to this ToR. For example, is it part of a World Bank-funded technical assistance (TA) project or similar?

1 BACKGROUND

This Terms of Reference (ToR) is for the completion of a risk evaluation and associated risk management planning tasks for road geohazards. It has been produced to align with the methodologies and approaches defined in the "Road Geohazard Risk Management Handbook" (in particular, Part III: Systems Planning).

This ToR covers the following roads ("The Roads") that are administered by the <<Insert Road Authority Name>> ("The Road Authority"):

<<insert a listing of roads, or geographic description, and map to ensure the consultants are aware of the scope of the road network under evaluation. Although this ToR is prepared on the basis of an existing road network, it is equally applicable to the identification of risks on a new route—although it is seldom that such activities would be separately undertaken from the overall route design process>>.

The Road Authority notes the following observations regarding its own management of road geohazard risks and the associated risks that The Roads are exposed to:

<<Replace following bullet points with relevant comments on the current status>>

- Government's role and stance regarding road geohazard risk management
- Is the work delivered using in-house resources, or is some outsourced to private sector consultants or contractors?
- Current status of road sector and road network development: for instance, well-developed road network, basic infrastructure
- Condition or characteristics of natural disasters: for instance, wide-scale flooding or mountain landslides
- Examples of road damage events by geohazards: for instance, in 2016 there was a major flood that xxx
- Needs for road geohazard risk management

The background should also provide an overview of the following to enable the Consultant to understand the likely effort involved in the ToR:

- Related laws and regulations
- Technical standards
- Existing risk management manuals (including for non-geohazard risks)
- Organization charts
- Ledgers of roads, geohazard locations, and road maintenance facilities (ideally all plotted on a map).

2 OBJECTIVES

The objectives of the Risk Evaluation of road geohazards is to identify and prioritize the management of hazard-prone road locations.

Whether it be a network-level analysis or a project-level analysis, the purpose of the Risk Evaluation process is to prioritize hazard-prone road locations for the subsequent application of risk mitigation. The evaluation results from this ToR will be used by the Road Authority as the initial decision-making process for next steps such as

- Remedial measures (works for minor damage portions conducted without the need for designs);
- Engineering studies for proactive risk management measures;
- Routine visual inspections only; or
- No further action in the case of low-priority risks

This analytical study aims to support the Road Authority in identifying, assessing, and prioritizing interventions and policies to enhance the transport network's resilience to natural hazards and climate change. The Consultant will develop and use a geospatial model to assess investments and policies (for example, structural measures, asset maintenance, asset rehabilitation, and other types of interventions) to enhance resilience of the network through a socioeconomic lens. Additionally, the assessment will assess the relative contribution to enhanced resilience of the transport network to uncertain risks associated with natural hazards and climate change impacts. Criticality is defined as the variation in network performance (total road user costs) when a transport link is disrupted, and vulnerability is defined as the ability to withstand natural hazards and climate change impacts.

Although this study focuses on The Roads noted above, the modeling of the road user costs will necessitate inclusion of other road categories to develop a road network model that has sufficient links to enable the modeling of traffic rerouting should road closure occur and alternative routes be available. It is not, however, a requirement of this ToR to produce a fully detailed traffic model that is suitable for all traffic modeling purposes; rather, a simplistic model that is fit-for-purpose to ascertain road link criticality is needed. [note: If the Road Authority already has a traffic model of sufficient detail, then this paragraph should be removed and, instead, reference made to the existing model and the Consultant's use of it.]

3 SCOPE OF WORK

The scope of work for the Risk Evaluation consulting services is described below. In summary, the requirements are

- Collection of data and information about geohazards within the vicinity of The Roads;
- Complete hazard mapping of the area that The Roads pass through;
- Use of decision making under deep uncertainty (DMDU) techniques to prioritize The Roads for investment; and
- Completion of preliminary option selection to mitigate the risks on all medium-, high-, or very-high-priority sites on the basis of the lowest life-cycle cost.

Further details on each of these steps are provided below.

3.1 Collection of Data and Information

Data and information on the evaluation of the geohazard risk of The Roads and surrounding areas should be collected in geographic information system (GIS) format. These comprise topographic maps, soil maps, aerial photos, satellite images, records of historical geohazards and/or road damage events, existing hazard-indicating maps, road inspection records, river or streamline maps, precipitation records, temperature records, and any other relevant information and data.

3.2 Detailed Hazard Mapping of Areas that The Roads Pass Through

The detailed hazard mapping of areas through which The Roads pass is to be completed. The purpose of detailed hazard mapping is to show the types of geohazards present in the landscape ecosystem areas through which The Roads will pass. The scope of the map indicating the hazards is from the hilltop to the bottom of the valley in the landscape ecosystem areas that The Roads will pass or are passing.

The hazard map should show all the types of geohazard locations, including historical hazard event information as well as potential geohazards. It is not too detailed and is provided with a small diminishing scale (1:10,000 to 1:50,000). It is mostly formulated by interpretation of contour maps, aerial photographs, and satellite images with available information on historical hazard events. In addition, field reconnaissance and interviews are conducted.

The detailed hazard map should indicate the hazard locations and the types of geohazards present in the landslide ecosystem areas of the planned new-road alignment. The locations of previous hazards, progressing hazards, or susceptibility to hazards are indicated as follows, by geohazard type:

- Fall- or collapse-type geohazard: source of rock or soil fall or collapse and its potential accumulation-area boundary
- River erosion: area of riverside erosion
- Slide-type geohazard: area of sliding mass and its potential movement-range boundary
- Flow-type geohazard (earth or debris flow): occurrence source and its potential accumulation-area boundary
- Flow-type geohazard (flooding): historical flooding area.

An inventory should be prepared for hazard-prone locations or areas using all the collected data and available information as well as field reconnaissance and interviews. The inventory of hazardous locations or areas includes, but is not limited to, location (coordinates, municipality, community); geohazard type; dimensions of hazardous area; assumed damage situation; finding on abnormalities; historical hazard events (if any); photographs of survey data; photographs of historical situations (if any); sketches (optional); date of inventory formulation or update; and names of inspection and recording personnel. Progress Report (II) should include the hazardous locations inventory, tabulated summary, diagrams, and summary text of collected data.

For each geohazard location, the expected impact of each geohazard type under a range of exposure levels shall be estimated. This information will subsequently inform the DMDU process.

3.3 Prioritization of Road Links Using DMDU

Using DMDU techniques, the Consultant is to identify the priority of each site. The Consultant is to follow the five-step DMDU process, as described in the Road Geohazard Risk Management Handbook (Section 3.6.3):

1. Determine the criticality of a road link
2. Determine the exposure of the road link to geohazard events
3. Determine the vulnerability of the road link to geohazard events
4. Determine the risk to the infrastructure (expected annual damage to the infrastructure)
5. Calculate the resultant priority of the road link.

Further detail on each of these steps is provided below. In addition, the Consultant is referred to the full Road Geohazard Management Handbook referenced in Section 1 of this ToR.

Step 1: Determine the criticality of a road link. To determine the criticality of each road link, the Consultant should estimate the change in the total road user costs (RUCs) from a system such as HDM-4 or a Client-approved alternative. (The Consultant is to specify, within the Inception Report, the methodology that will be adopted for assessing the RUCs.) The Consultant will need to proceed as follows:

- Define origin–destination (O–D) centers and estimate the traffic volumes between the pairs. The traffic volumes (O–D pairs) should consider, as a minimum, the a.m. and p.m. peak periods plus an interpeak period. The Consultant shall advise on the need for off-peak and weekend traffic O–D matrices.
- Develop an appropriate traffic model that covers all of The Roads, plus such other roads (of any hierarchy and managed by any road authority) that may be required to yield an appropriate traffic model that can reassign traffic in the event of road closures. The model does not need to be multimodal unless a change in modes is a realistic option for road closures of the duration that would reasonably be expected for the nature of geohazards under investigation. Locations of high geohazard risk shall be identifiable within the model, such as areas of unstable land or river crossings.
- Develop RUC functions for each road link in the traffic model, including considerations of traffic congestion should peak-hour traffic volumes exceed 75 percent of the link capacity.

To undertake the DMDU analysis, The Roads will need to be split into shorter road links. The Consultant shall determine the appropriate split points for the road links based on the overall road network (all road hierarchies) and not just the selected Roads administered by the Road Authority. In particular, the Consultant is to note that the shorter (more homogeneous) the link, the simpler the estimation of the road link's vulnerability (Step 2, below).

Where the data necessary to prepare the above traffic model are not available, the Consultant may propose (for Client's acceptance) an alternative means of assigning criticality to each road link. In such a case, the Consultant shall prepare a methodology for assigning criticality, considering factors such as the road hierarchy; traffic volumes; public services along the route (hospitals, schools, and so on); length of alternative routes; and other relevant factors that the Consultant and Client deem appropriate. The Consultant shall then use these factors to assign a criticality score to each road link.

Step 2: Determine the exposure of the road link to geohazard events. Based on a combination of geotechnical, hydrological, and engineering assessments, the Consultant is to

- Define the range of causes of geohazards (for example, rainfall or earthquakes) to be examined under the DMDU process;
- Define the types of geohazards that The Roads are exposed to as a result of the causes;
- Define a minimum of 5 (and maximum of 10) exposure levels for each different geohazard cause (for example, different rainfall intensity probability events); and
- For each combination of geohazard cause and exposure level, estimate the impact on each road link within the traffic model. A minimum of three possible results are to be considered:
    - 1 = No impact on traffic flow
    - 2 = Partial reduction in road capacity (assume 50 percent)
    - 3 = Full loss of road capacity.

Step 3: Determine the vulnerability of the road link to geohazard events. For each scenario considered in Step 2 above, the cost impact to the Road Authority to repair The Roads shall be estimated.

Step 4: Determine the risk to the infrastructure (expected annual loss to the infrastructure). When combined with the probability of the scenario, the expected annual loss (EAL) calculation provides the inputs to assess the risk to the infrastructure. (For a detailed discussion of the EAL, see Section 3.6.3.4 of the Road Geohazard Management Handbook.)

Step 5: Calculate the resultant priority of the road link. Combining the above model outputs and the DMDU methodology contained in the Road Geohazard Management Handbook (Section 3.6), the Consultant is to determine the priority of each road link. This information shall be made available to the Road Authority in both tabular and map (ArcGIS) format.

3.4 Life-Cycle Cost Analysis of Mitigation Measures

For all geohazard sites on The Roads that are assessed as being of a medium, high, or very high priority (as determined by the DMDU process), the Consultant is to identify mitigation measures (considering both structural and nonstructural measures) and complete a preliminary evaluation of each solution using generic concept solutions (no site-specific tests, surveys, or designs are required).

The generic concept sketches shall be prepared for a range of mitigation solutions that indicate the typical form of the works and that are suitable for preparation of a typical costing of the solution. Costing estimates are expected to have an accuracy of ±30 percent [This figure should be amended to reflect what is reasonable within a country, based on the limited design information that is available] when considered at the network level. (It is understood that the Consultant will not have sufficient information to yield highly reliable cost estimates for any given geohazard site, but it is expected that a reasonable overall assessment of the costs at a network level can be made.) The estimates will be used as the basis for budget allocation for the subsequent detailed design and construction stages. For each measure, the expected life-cycle costs (operations and maintenance) over the next 30 years [To be aligned with standard economic evaluation practices in the Road Authority] shall be estimated for each geohazard exposure level tested within the DMDU process.

For each geohazard site, a matrix is to be prepared to indicate which of the "concept solutions" is applicable to that site—noting that many different solutions may be applicable to each site.

The Consultant is to develop a weighted estimate of the life-cycle costs and RUC impacts from road closures for each of the exposure levels tested at each geohazard location. These outputs shall then be used to determine the concept solution that offers the overall lowest net present value (NPV, that is, the lowest expected cost considering both RUCs and Road Authority costs).

4 DELIVERABLES

Each deliverable shall be provided first as a draft, and after Client's feedback will be submitted in final form. Unless otherwise directed, the acceptance of each deliverable by the Client shall be treated as a contract hold point. The Client may request a workshop on any of the deliverables once they have had time to review the Draft Final Report.

4.1 Inception Report

The Consultant shall show an understanding of the background and the objective of the Work, confirm contents of the Work (tasks), and prepare a work plan with methodology in the Inception Report (IR). The IR shall be submitted to the Client for approval.

4.2 Progress Reports

The Consultant shall prepare Progress Report (I), which shall include the results of the data collection, geohazard map, and the inventory of hazardous locations and areas in the landscape ecosystems that The Roads pass through (optional for existing roads). In addition, the Consultant shall prepare Progress Report (II), which shall include the risk evaluation procedure and results. The report also should contain the geohazard risk management planning procedure.

4.3 Final Report

The Consultant shall prepare the Final Report, which shall include all the results of the tasks described herein, including the risk evaluation results; the evaluation procedures and criteria; and the recommendations for the possible planning, design, and implementation of the project.

The Consultant shall revise and update the contents of the Draft Final Report by considering comments from the Client. All the documents on the risk evaluation shall be finalized and included in the Final Report. Collected data and output maps must be submitted to the Client upon completion of the project. Outputs shall be in a format suitable for subsequent analysis—such as Microsoft Excel tables, ArcGIS shape files, or similar.

5 SCHEDULE

[Note that the duration of this ToR will be related to the scope of road network included. If extended to a full road network, then the duration will likely exceed one year. Conversely, for a single, small hazard-prone location, it may be possible to complete the tasks in three to four months. As with the comments on the skills and experience required, the Client will need to ensure that the inputs are appropriate for the scope of works.]

[All periods and dates to be reviewed to account for specific situations]

All tasks shall be completed within 200 working days after contract effectivity, according to the schedule outlined below. In addition, meetings, seminars, or workshops shall be planned as necessary.

- Submission of Inception Report: within 15 days after contract effectivity. The Consultant shall prepare the IR, which shall include the table of contents, methodology, and schedule of the country capacity review. Copies of the IR shall be delivered to the Client. The Consultant shall orally explain the IR's contents in a presentation upon delivery of the IR to the Client.

- Submission of Progress Report (I): within 45 days after contract effectivity. The Consultant shall prepare and submit Progress Report (I), which should describe the progress of the Work to the Client.
- Submission of Progress Report (II): within 60 days after contract effectivity. The Consultant shall prepare and submit Progress Report (II), which should describe the progress of the Work to the Client.
- Completion of Traffic Modeling: within 100 days after contract effectivity. All traffic model outputs shall be complete and reported. This includes full reporting of the O–D model development; the RUC model in use; the sectioning of The Roads into links; and the resultant outputs from the model.
- Submission of Draft Final Report: within 90 days after contract effectivity. The Consultant shall prepare and submit a Draft Final Report that includes all the results of the Work. The Consultant shall orally explain the Draft Final Report's contents in a presentation upon delivery of the Draft Final Report to the Client. The Consultant shall collect comments on the Draft Final Report from the Client.
- Submission of Final Report: within 120 days after contract effectivity. The Consultant shall prepare and submit the Final Report, which shall contain the required revisions to the contents of the Draft Final Report based on the comments from the Client. The Consultant shall submit all the deliverables, including the Final Report, to the Client.

6 PROFESSIONAL SKILLS AND EXPERIENCE REQUIRED

The Consultant's team will include qualified personnel with extensive experience in geotechnical engineering, hydraulic engineering, climate Modeling, risk assessment, civil engineering, and traffic Modeling. The consulting firm shall have sufficient qualified personnel and resources, including international technical expertise and advisers, to provide all necessary professional, technical, and expert services required to accomplish all the services described above within the prescribed time.

The Consultant shall assemble a team for undertaking the scope of work and tasks described above. In responding to the ToR, consultancy organizations will provide curricula vitae, a description of roles and responsibilities, and a written statement of exclusivity and availability of key experts who will be working on the project.

Consulting firms may form joint ventures or associations with other consulting firms to enhance their capabilities, strengthen the technical responsiveness of their proposals, make available bigger pools of experts, and enhance the value and quality of their services. The following key personnel (whose experience and responsibilities are briefly described) will be considered in the evaluation of the technical proposals. Other expertise as required for the services to be rendered should be included as necessary and reflect the Consultant's responsiveness to the ToR.

It is estimated that this project will require 22 person-months from the team and will be completed within a period of 10 months. A list of suggested key personnel to be deployed by the Consultant, with appropriate minimum person-months of each as per Client's assessment, is shown in Table A.2.1. However, the Consultant can make their own assessment for the required composition and person-months for the key personnel and the phasing of their mobilization. The adequacy of the proposed composition will be assessed in the context of the proposal.

[The Client will need to review these inputs in the context of the extent of The Roads to be assessed and the existence of traffic models that can be used. Large road networks with no existing traffic models will naturally take greater inputs than small road networks with an existing traffic model in place.]

Table A.2.1 Estimated Input of Key Professional Staff

No.	Position	Person-months
1	Team leader or project manager	7
2	Geotechnical specialist	4
3	Hydraulic engineer	4
4	Civil engineer	4
5	Traffic modeler	3
Total estimated key staff person-months		22

The person nominated as the team leader or project manager may also be nominated for any of the other roles.

Minimum qualifications and experience of key professional staff are summarized in Tables A.2.2–A.2.6. However, the Consultant may propose an effective team considered to be the most suitable for carrying out the project. The technical proposal must outline why the proposed composition of the team is considered capable and most suitable. In particular, many of the outputs require the use of geographic information systems (GIS) systems (such as ArcGIS), and the Consultant is to ensure that such skills exist within the team.

Table A.2.2 Qualifications and Skills of Team Leader or Project Manager

Qualifications and skills	Minimum of a master's degree in civil or highway engineering, computer science or information and communication technology (ICT), or a related topic, or equivalent professional experience of at least 15 years Fluency in English <<and Add other language as required>> language, both written and oral
General professional experience	At least 10 years of professional engineering experience
Specific professional experience	• Proven leadership and people management skills, including the ability to establish and maintain effective working relationships in an international multicultural working environment • Experience regarding work activities in transitioning or low- and middle-income countries • Experience in providing training or knowledge transfer to Client staff preferred • Minimum of 10 years' experience covering at least one aspect of the activities within this ToR (geotechnical, hydraulics, risk assessment, and so on)
Key responsibilities	• Provide overall management of all project activities • Coordinate and supervise the consultancy team, serving as the primary point of contact with the Client • Ensure high-quality deliverables • Lead the review and updating of the risk-based framework

Table A.2.3 Qualifications and Skills of Geotechnical Specialists

Qualifications and skills	Minimum of a master's degree in civil, road, or geotechnical engineering or a related topic, or equivalent professional experience of at least 10 years Fluency in English language, both written and oral
General professional experience	Expertise and experience in activities relating to life-cycle management of geotechnical assets
Specific professional experience	• At least 10 years of professional experience in areas relevant to this project • Understanding of landslide hazards and failure mechanisms of geotechnical assets • Understanding of risk-based evaluation methodologies preferred
Key responsibilities	Lead all geotechnical aspects of the assignment: develop land movement scenarios, estimate consequences, and so on

Table A.2.4 Qualifications and Skills of Hydraulic Specialist

Qualifications and skills	Minimum of a master's degree in civil, road, or geotechnical engineering or a related topic, or equivalent professional experience of at least 10 years Fluency in English language, both written and oral
General professional experience	Expertise and experience in activities relating to life-cycle management of geotechnical assets
Specific professional experience	• At least 10 years of professional experience in areas relevant to this project • Understanding of hydraulic modeling of catchments, climate modeling, and impact on road infrastructure • Understanding of risk-based evaluation methodologies preferred
Key responsibilities	Lead all geotechnical and hydraulic aspects of the assignment: develop hydraulic scenarios, estimate consequences, and so on

Table A.2.5 Qualifications and Skills of Civil Engineer

Qualifications and skills	Minimum of a master's degree in civil, road, or geotechnical engineering or a related topic, or equivalent professional experience of at least 10 years. Fluency in English language, both written and oral
General professional experience	Expertise and experience in estimating the costs of highway works
Specific professional experience	• At least 10 years of professional experience in areas relevant to this project • Understanding of road damage caused by geohazards • Understanding of risk-based evaluation methodologies preferred
Key responsibilities	Develop cost estimates of damages to the road infrastructure for the scenarios under analysis

Table A.2.6 Qualifications and Skills of Traffic Modeler

Qualifications and skills	Minimum of a master's degree in civil, road, or geotechnical engineering or a related topic, or equivalent professional experience of at least 10 years Fluency in English language, both written and oral
General professional experience	Expertise in the development of network-level traffic models
Specific professional experience	• At least 10 years of professional experience in areas relevant to this project • Development of origin–destination (O–D) models, from data survey techniques to model calibration and application • Detailed working knowledge of the traffic modeling platform proposed for use by the Consultant
Key responsibilities	Lead all aspects of the traffic modeling within this ToR

APPENDIX A.3

Terms of Reference 3 (ToR 3)

DEVELOPMENT OF MANUAL FOR PROMOTION OF ROAD DISASTER AWARENESS AND PARTNERSHIP

Ideally the development of a Manual for Promotion of Road Disaster Awareness and Partnership would be based around the full scope of disasters that a road authority deals with, and not just be confined to geohazard emergencies.

In the absence of a broader manual being in place, this ToR has been developed to develop an awareness manual with a geohazard focus. Alternatively, the contents of this ToR could be expanded upon to develop a ToR for an overall response and recovery plan covering all disaster events.

1 BACKGROUND

This box is to be deleted once ToR is completed by the road authority.

Provide a paragraph or two on the background to this ToR. For example, is it part of a World Bank-funded technical assistance (TA) project or similar?

This terms of reference (ToR) is for the development of a Manual for the Promotion of Road Disaster Awareness and Partnership in relation to geohazards. The intent of the Manual is to create an environment in which human activities to increase the risk of geohazards is minimized; road users are effectively informed of geohazards and road closures; and appropriate stakeholder engagement is occurring. This ToR has been produced to align with the methodologies and approaches defined in the "Road Geohazard Risk Management Handbook."

This ToR covers the <<Insert Road Authority Name>> (the "Road Authority") that is responsible for the development, operations, and maintenance of the <<Insert road hierarchy>> road network within <<Insert country and/or state name>>. The ToR covers all areas of operation within the Road Authority that reasonably affect road geohazard risk management. The development of the Manual will necessitate consultation with a wide range of stakeholders as further elaborated on within this ToR.

The Road Authority notes the following observations regarding its own management of road geohazard risks and the associated risks that the road network is exposed to:

<<Replace following bullet points with relevant comments on the current status>>

- Government's role and stance regarding road geohazard risk management
- Is the work delivered using in-house resources, or is some outsourced to private sector consultants or contractors?
- Current status of road sector and road network development: for instance, well-developed road network, basic infrastructure
- Condition or characteristics of natural disasters: for instance, wide-scale flooding or mountain landslides
- Examples of road damage events by geohazards: for instance, in 2016 there was a major flood that xxx
- Needs for road geohazard risk management

2 OBJECTIVE

The objective of the proposed work is to develop the Manual for Promotion of Road Disaster Awareness and Partnership for road geohazard risk management. The Manual is intended to enhance road geohazard risk management through the following road stakeholder contributions:

- ***Controlling road disasters caused by human activities.*** Human activities often trigger road geohazards (for example, garbage accumulation in the road drainage can reduce the effectiveness of the drainage to cause a road geohazard). Significant water use (such as irrigation), deforestation, banking of the potential sliding slope head, or cutting the slope foot may cause road geohazards as well. Increased public awareness can help control and stop harmful human activities that can induce road geohazards. In addition, control of land use through laws and regulations is necessary for the prohibition of said harmful activities.
- ***Raising road geohazard awareness through traffic signs.*** Traffic signs can be installed to inform road users of endangered road locations, geohazard-prone road subsections, or road subsections selected for precautionary road closure to protect road users from geohazards.
- ***Awareness raising and training for road stakeholders.*** Engagement of road stakeholders (such as road users or residents near the road) involves the provision of information on any geohazard abnormality in order to prevent the geohazard through early proactive measures or precautionary road closing, thus helping to prevent road user inconvenience or suffering. Practical actions include an awareness campaign through training of road stakeholders, a road safety campaign, or a community disaster evacuation drill.

3 SCOPE OF WORK

The Work is split into two phases.

3.1 Phase I

3.1.1 Collection and Arrangement of Data and Information

The Consultant shall collect data and information concerning road disaster awareness promotion for road users, residents, and business establishments that are adjacent to (or have a significant impact on) the road network operated by the Road Authority. The data and information shall include, for example, hydrological and meteorological data, traffic laws and regulations pertaining to road closures, land use conditions along the subject roads, related programs and activities, educational materials, existing coordination mechanisms between the road sector and other sectors, information sharing among stakeholders, volunteer support programs for road disaster risk management and awareness raising, road geohazard disaster records, garbage treatment on the roads, condition of drainage systems, vegetation condition and control, and installation requirements for signboards or banners for road disaster awareness.

Annex A.3.1 contains a nonexhaustive listing of information that the Road Authority believes to be relevant to this assignment; however, the Consultant shall exercise their judgment and expertise to determine which of those items listed require full review and also to seek out other information that is pertinent to this assignment.

The Consultant is to develop a series of maps in ArcGIS format (or similar other formats as approved by the Road Authority) that illustrate the general nature of geohazards across the road network. These maps are not for the identification of specific locations of geohazards (for example, a landslide at

KMxxx on road 123) but rather to illustrate the general location of different geohazard zones (such as areas of high flooding risk, areas of high landslide risk, and so on).

All data that can be reasonably geolocated shall be mapped to enable a visual understanding of where the geohazard risk is high, where geohazard awareness information has been provided, alternative routes if roads are closed, and so on.

3.1.2 Interview Survey and Site Observation

The Consultant shall interview representatives of the following organizations or groups to understand road disaster awareness-related activities as well as the local or institutional partnerships for geohazard risk reduction:

- Local road management authorities
- Municipal, regional, and central government agencies
- Disaster risk management authorities (if separate from the road management authority)
- Technical institutions for roads or geohazard risk management (if present)
- Police
- Rescue agencies
- Meteorological agencies
- River (land scope ecosystem) management authorities
- Executives of national and local governments
- Environmental organizations
- Urban and rural development organizations
- Road users
- Residents, business establishments, and other persons along the roads
- Public transport companies and associations
- Service agencies or companies (water supply, drainage, electricity, communication, and fuel) or other companies that install facilities on the roadside or road subsurface.

The Consultant shall verify road disaster awareness and partnership activities, whether these are occurring formally or informally. Current implementation mechanisms, number of staff, budget, and other issues concerning road disaster awareness performance and partnership shall be examined. The Road Authority will assist in facilitating meetings with the organizations and groups listed above—with the Consultant to clarify whether one-on-one or workshop-style sessions are required.

3.2 Phase II

3.2.1 Methodology Development

The Consultant shall develop the methodologies for promoting road disaster awareness and local or institutional partnerships for road geohazard risk management, based on the results of Phase I work. In developing the methodologies, the following should be taken into consideration:

- Basic policy on road disaster awareness promotion and local or institutional partnerships for road geohazard risk management

- Activities for road disaster awareness promotion
- Implementation mechanisms (including local or institutional partnerships) for road geohazard risk management
- Introduction of a private volunteer support program for road geohazard risk management
- Information sharing among road users and other stakeholders.

The methodology shall reflect the differing risk levels that exist across the road network, with a clear resultant priority of investments in the implementation of the Manual being developed by the Consultant for the Road Authority. (This may potentially span many years if, for instance, a nationwide series of electronic sign boards were recommended for implementation.)

3.2.2 Preparation and Development of the Manual

The Consultant shall prepare a Manual describing the methodologies for promoting road disaster awareness and road geohazard risk management-related activities. The Manual should include useful tools, plans and programs, awareness campaign materials, templates of leaflets or signboards, and other reference materials.

The Manual shall also include draft service agreements or similar documents for the Road Authority to use to enter into an agreement with other stakeholders in relation to geohazard risk management.

3.2.3 Final Workshop(s)

A workshop shall be held to present and explain the Manual for Promotion of Road Disaster Awareness and Partnership to the Road Authority's staff and key stakeholders. The Consultant shall present practical methodologies in the proposal to the Road Authority. In agreement with the Road Authority, more than one such workshop may be necessary to ensure geographic coverage of the Road Authorities' area of responsibility.

4 DELIVERABLES

All deliverables shall be provided first as a draft, and after Client's feedback shall be submitted in final form. Unless otherwise directed, the acceptance of each deliverable by the Client shall be treated as a contract hold point. The Client may request a workshop on any of the deliverables once they have had time to review the Draft Final Report.

4.1 Phase I

4.1.1 Inception Report

The Consultant should show an understanding of the background and the objective of the Work, confirm the contents of the Work (tasks), prepare the work plan, and submit the Inception Report (IR) to the Road Authority.

4.1.2 Phase I Progress Report

The Consultant shall tabulate all collected data and information and map them to identify current problems on the activities for road disaster awareness and local or institutional partnerships for road geohazard risk management. The Consultant shall prepare a Phase I Progress Report comprising the current conditions of road disaster awareness, local or institutional partnerships for road geohazard risk management-related activities, and the identified problems. The Phase I Progress Report also shall include the plan of activities for Phase II.

4.2 Phase II

4.2.1 Methodology Development

The Consultant shall fully document the methodologies developed for promoting road disaster awareness and local or institutional partnerships for road geohazard risk management. The Consultant shall submit the draft methodology to the Road Authority and subsequently convene a meeting to discuss if the Client requests.

4.2.2 Manual

The Consultant shall submit the Draft Manual to the Road Authority and subsequently convene a meeting to discuss if the Client requests. Upon receipt of feedback from the Road Authority, the Consultant shall finalize the Manual.

4.2.3 Draft Final Report

The Consultant shall prepare a Draft Final Report that includes all the results of the tasks as well as the Manual for Promotion of Road Disaster Awareness and Partnership. The Draft Final Report shall be submitted to the Road Authority, with a subsequent workshop arranged by the Consultant to present the findings and recommendations to the Road Authority. The workshop shall take place within 10 working days after submission of the Draft Final Report, and the Road Authority will determine which (if any) of the stakeholders are to be invited to the workshop.

4.2.4 Final Report

The Consultant shall revise and update the contents of the Draft Final Report considering comments from the Road Authority. The Manual shall also be finalized and included in the Final Report.

4.2.5 Final Workshop(s)

A copy of all presentation materials used at the workshop shall be provided in both Microsoft PowerPoint and Adobe PDF formats.

5 SCHEDULE

All tasks shall be completed within 180 days after contract effectivity according to the schedule outlined below. Note: The duration of the Consultant's tasks should be revised in consideration of the size of the road network (and hence the number of stakeholders) to be engaged.

- Submission of Inception Report: within 10 days after contract effectivity. The Consultant shall prepare an IR comprising the contents, methodologies, and a schedule for development of the Manual. Copies of the IR shall be submitted to the Road Authority in electronic format plus one hard copy. The Consultant shall present and discuss the contents of the IR with the Road Authority.
- Submission of Phase I Progress Report: within 60 days after contract effectivity. The Consultant shall prepare a Draft Phase I Progress Report comprising the contents mentioned in section 4.1.2. Copies of the Draft Phase I Progress Report shall be delivered to the Road Authority in electronic format plus one hard copy. The Consultant shall present and discuss the contents of the Draft Phase I Progress Report with the Road Authority. The Consultant shall prepare the Final Phase I Progress Report within 10 days of receiving feedback on the Draft Phase I Progress Report from the Road Authority.
- Submission of Draft Manual for Promotion of Road Disaster Awareness and Partnership: within 90 days of submission of the draft progress report. The Consultant shall prepare and submit the Draft Manual for review by the Road Authority and those stakeholders selected by the Road Authority. The

Consultant shall present and discuss the contents of the Draft Manual with the Road Authority in a workshop-style setting including selected stakeholders. The Road Authority will be responsible for consolidating feedback on the Draft Manual.

- Submission of Draft Final Report: within 90 days of submission of the Draft Phase I Progress Report. The Consultant shall prepare a Draft Final Report, comprising all of the results of the Work, for review by the Road Authority and those stakeholders selected by the Road Authority. The Draft Manual for Promotion of Road Disaster Awareness and Partnership is to be submitted as a stand-alone document, as noted above. The Draft Final Report shall be submitted to the Road Authority in electronic format plus one hard copy. The Consultant shall present and discuss the contents of the Draft Final Report with the Road Authority in a workshop-style setting including selected stakeholders. The Road Authority will be responsible for consolidating feedback on the Draft Final Report.
- Submission of Final Report: within 30 days of feedback on the Draft Manual and Draft Final Report. The Consultant shall prepare the Final Report and final Manual for Promotion of Road Disaster Awareness and Partnership, revising the contents based on the comments from Road Authority. The Consultant shall submit all the deliverables, including the Final Report, to the Road Authority in both electronic format and five hard copies.

All reports shall be in the language(s) of English and <<enter a second language if required>>. In addition to the specified number of hard copies, electronic submissions shall be in the following formats:

- Draft reports need only be in PDF format, with permissions set to enable copying of contents and insertion of comments.
- Final reports are to be provided in both PDF format and in an editable format such as Microsoft Office (Word, Excel, and so on); ArcGIS; or another approved format.

6 PROFESSIONAL SKILLS AND EXPERIENCE REQUIRED

The Consultant's team will include qualified personnel with extensive experience in communications, geotechnical engineering, hydraulic engineering, risk assessment, civil engineering, and traffic modeling. The consulting firm shall have sufficient qualified personnel and resources, including international technical expertise and advisers, to provide all necessary professional, technical, and expert services required to accomplish all the services described above within the prescribed time.

The Consultant shall assemble a team for undertaking the scope of work and tasks described above. In responding to the ToR, consultancy organizations will provide curricula vitae, a description of roles and responsibilities, and a written statement of exclusivity and availability of key experts who will be working on the project.

Consulting firms may form joint ventures or associations with other consulting firms to enhance their capabilities, strengthen the technical responsiveness of their proposals, make available bigger pools of experts, and enhance the value and quality of their services. The following key personnel (whose experience and responsibilities are briefly described) will be considered in the evaluation of the technical proposals. Other expertise as required for the services to be rendered should be included as necessary and to reflect the Consultant's responsiveness to the ToR.

[The Client will need to review these inputs in the context of geohazards present on the network.]

It is estimated that this project will require 22 person-months from the team and will be completed within a period of 10 months. A list of suggested key personnel to be deployed by the Consultant with appropriate minimum person-months of each as per Client's assessment is shown in Table A.3.1. However, the Consultant can make their own assessment for the required composition and person-months for the key personnel and the phasing of their mobilization. The adequacy of the proposed composition will be assessed in the context of the proposal.

Table A.3.1 Estimated Input of Key Professional Staff

No.	Position	Person-months
1	Team leader or project manager	7
2	Communications specialist	6
3	Geotechnical specialist	1
4	Hydraulic engineer	1
5	Civil engineer	1
6	Traffic modeler	1
Total estimated key staff person-months		17

The person nominated as the team leader or project manager may also be nominated for any of the other roles.

The minimum qualifications and experience of key professional staff are summarized in Tables A.3.2–A.3.7. However, the Consultant may propose an effective team considered to be the most suitable for carrying out the project. The technical proposal must outline why the proposed composition of the team is considered capable and most suitable. In particular, many of the outputs require the use of geographic information systems (GIS) such as ArcGIS, and the Consultant is to ensure that such skills exist within the team.

Table A.3.2 Qualifications and Skills of Team Leader or Project Manager

Qualifications and skills	Minimum of a master's degree in civil or highway engineering, computer science or information and communication technology (ICT), or a related topic, or equivalent professional experience of at least 15 years Fluency in English <<add other language as required>> language, both written and oral
General professional experience	At least 10 years of professional engineering experience
Specific professional experience	• Proven leadership and people management skills, including the ability to establish and maintain effective working relationships in an international multicultural working environment • Experience regarding work activities in transitioning or low- and middle-income countries • Experience in providing training or knowledge transfer to Client staff preferred • Minimum of 10 years' experience covering at least one aspect of the activities within this ToR (geotechnical, hydraulics, risk assessment, and so on)
Key responsibilities	• Provide overall management of all project activities • Coordinate and supervise the consultancy team and serve as the primary point of contact with the Client • Ensure high-quality deliverables • Lead the review and updating of the risk-based framework

Table A.3.3 Qualifications and Skills of Communications Specialist

Qualifications and skills	Minimum of a bachelor's degree in a relevant field and equivalent professional experience of at least 15 years Fluency in English language, both written and oral
General professional experience	At least five years of experience in communications related to transport projects
Specific professional experience	• Proven ability to take technical inputs from other team members and produce a high-quality communication document suitable for both technical and nontechnical readers • Experience regarding work activities in transitioning or low- and middle-income countries • Experience in writing communications documents for transport authorities (any mode) • Experience working on at least one disaster awareness project in the past five years preferred
Key responsibilities	Overall lead for the development and writing of the Manual

Table A.3.4 Qualifications and Skills of Geotechnical Specialists

Qualifications and skills	Minimum of a master's degree in civil, road, or geotechnical engineering or related topic, or equivalent professional experience of at least 10 years Fluency in English language, both written and oral
General professional experience	Expertise and experience in activities relating to life-cycle management of geotechnical assets
Specific professional experience	• At least 10 years of professional experience in areas relevant to this project • Understanding of landslide hazards and failure mechanisms of geotechnical assets • Understanding of risk-based evaluation methodologies preferred
Key responsibilities	Lead all geotechnical aspects of the assignment: develop land movement scenarios, estimate consequences, and so on

Table A.3.5 Qualifications and Skills of Hydraulic Specialist

Qualifications and skills	Minimum of a master's degree in civil, road, or geotechnical engineering or related topic, or equivalent professional experience of at least 10 years Fluency in English language, both written and oral
General professional experience	Expertise and experience in activities relating to life-cycle management of geotechnical assets
Specific professional experience	• At least 10 years of professional experience in areas relevant to this project • Understanding of hydraulic modeling of catchments, climate modeling, and impact on road infrastructure • Understanding of risk-based evaluation methodologies preferred
Key responsibilities	Lead all geotechnical and hydraulic aspects of the assignment: develop hydraulic scenarios, estimate consequences, and so on

Table A.3.6 Qualifications and Skills of Civil Engineer

Qualifications and skills	Minimum of a master's degree in civil, road, or geotechnical engineering or related topic, or equivalent professional experience of at least 10 years Fluency in English language, both written and oral
General professional experience	Expertise and experience in estimating the costs of highway works
Specific professional experience	• At least 10 years of professional experience in areas relevant to this project • Understanding of road damage caused by geohazards • Understanding of risk-based evaluation methodologies preferred
Key responsibilities	Develop cost estimates of damages to the road infrastructure for the scenarios under analysis

Table A.3.7 Qualifications and Skills of Traffic Modeler

Qualifications and skills	Minimum of a master's degree in civil, road, or geotechnical engineering or related topic, or equivalent professional experience of at least 10 years Fluency in English language, both written and oral
General professional experience	Expertise in the development of network-level traffic models
Specific professional experience	• At least 10 years of professional experience in areas relevant to this project • Development of origin–destination (O–D) models, from data survey techniques to model calibration and application • Detailed working knowledge of the traffic modeling platform proposed for use by the Consultant
Key responsibilities	Lead all aspects of the traffic modeling within this ToR

7 ANNEX A.3.1: LISTING OF RELEVANT INFORMATION

Attach a listing of information and data useful for the Manual for Promotion of Road Disaster Awareness and Partnership such as location maps, lists of technical standards to be applied, regulations and laws, and so on to be added by the Road Authority.

APPENDIX A.4

Terms of Reference 4 (ToR 4)

DESIGN OF STRUCTURAL MEASURES

This ToR contains suggested design parameters for safety factors. Where local design factors exist within a country or region, those should be used instead of the factors within this ToR.

Although this ToR covers the design of structural measures on both new and existing roads, in practice, for new roads the design of structural measures is likely to be part of an overall consulting assignment—including geometric alignment, traffic, social and environmental issues, and so on—such that this ToR may be used to help define the geohazard structural measures within the overall ToR.

It is possible that some aspects of this ToR (hazard mapping and the like) would already have been completed before the procurement of a design consultant. In such circumstances, the Background section should reflect this prior work and the relevant aspects of the ToR deleted or edited accordingly.

Depending on the type(s) of geohazards that are being designed for, some aspects of this ToR may be unnecessary and may be deleted.

1 BACKGROUND

This terms of reference (ToR) is for the design of structural measures for the mitigation of road geohazards on <<define the location of the project>> (the Project Site) that is administered by the <<insert road authority name >> (the Road Authority). This ToR has been produced to align with the methodologies and approaches defined in the “Road Geohazard Risk Management Handbook.”

This box to be deleted once the ToR is completed by the road authority.

Provide a paragraph or two on the background to this ToR. For example, is it part of a World Bank-funded technical assistance (TA) project or similar?

The following information shall be included in the background and then this box deleted:

- Summary of the project (location of the road or route, sections, and so on)
- Current status of the road
- The natural condition of the hazard-prone road locations (climate, topography, geology, and so on)
- Social and economic situation of transport in the area, which includes targeting hazard-prone road locations
- Other useful information for the design of structural measures

2 OBJECTIVES

The objectives of this ToR are to

- Investigate the cause of failure at the Project Site and estimate the likelihood and cost (to the Road Authority and road users) of future events;
- Analyze a range of mitigation options, including an assessment of construction, maintenance, and operational costs over a period of at least 30 years for each option; and
- Complete a detailed design and associated documentation for the Road Authority's preferred option, including the development of any relevant maintenance or operational manuals for the preferred design.

Recognizing that geohazards are seldom of a determinant nature, the Consultant is required to consider a range of solutions that have differing levels of resilience. These will range from simple "maintenance only" solutions to major structural solutions. The Consultant is required to estimate the life-cycle costs over a period of at least 30 years [replace with a period aligned with standard economic practice in the Road Authority] for each concept solution developed under a range of future geohazard events, with the output of such analysis used to identify a preferred solution.

Furthermore, it is noted that the Project Site is just one location within a road network and that achieving 100 percent resilience at the Project Site may make little difference to the overall road network resilience if many other low-resilience locations remain. The Consultant shall help the Road Authority determine the appropriate level of resilience to achieve at the Project Site, based on the likely level of investment available across the network.

All investigations and engineering designs are to be in compliance with the appropriate standards of the Road Authority unless otherwise approved by the Road Authority.

For the preferred option (as selected by the Road Authority), the detailed design phase shall include drawings, a bill of quantities, a cost estimate, technical specifications, and a recommendation on the best contractual model to undertake the works. Upon completion of the detailed design, the Consultant is to prepare Contract Documents for use by the Road Authority to procure the works.

3 SCOPE OF WORK

The tasks and deliverables of the required technical assistance services include the Inception Report, collection and arrangement of existing data and information, the engineering investigation, the Engineering Investigation Report, the Concept Design, the Detailed Design, and the Final Report.

3.1 Inception Report

The Consultant should show an understanding of the background and objectives of the Work, confirm the contents of the Work (tasks), and prepare the work plan for the engineering investigation and design work in the Inception Report (IR). The IR is then submitted to the Client.

3.2 Investigation of Cause and Impact of Failure

The Consultant is to collate and analyze such data (including field measurements) as is necessary to understand the cause of failure at the Project Site. The Consultant is to also estimate the likelihood of future events that could trigger further failures. Where appropriate, the future-likelihood assessments shall consider trigger-scenario events of different magnitudes, with their associated estimated impacts on the road network (for example, different rainfall probability events, or different-size earthquakes).

The impacts shall include both (a) the costs to the Road Authority of remediation measures after events if no further mitigation measures are in place, and (b) an assessment of the additional road user costs (RUCs) that the motorists would experience as a result of using alternative routes until the road could be reopened.

Note: As this is a generic ToR, it is not possible to specify the nature of such investigations. The Road Authority shall be more specific before using this ToR—noting whether the investigations include river flows, earthquake models, rain fall assessments, and so on.

The Consultant shall collect the available data on the following:

- Geographical information (such as topographic maps, aerial photographs, and satellite images) on the hazard-prone road location and the landscape ecosystem area for flow-type geohazards
- Geological maps and geological and geotechnical survey reports
- Record of the historical geohazard events (disaster records) in the landscape ecosystem areas
- Road planning reports
- Road construction records for the existing road
- Land classification and land use maps
- Critical nearby infrastructures (such as schools, hospitals, and power stations)
- Detailed hazard maps (for example, landslide distribution maps)
- Weather and climate data, including precipitation records
- Hydrological information on the road river-crossing point and/or river on the roadside (such as water elevation and river flow rate)
- Records of earth movements from past earthquakes.

The Consultant should use geographic information system (GIS) mapping to the extent possible to collate, analyze, and present this information. Table A.4.1 contains further details on the suggested data collection for concept design purposes.

Table A.4.1 Data Collection and Usage for Concept Design

DATA ITEMS	DATA DESCRIPTION	USAGE
Geographical information such as topographic maps, aerial photographs, and satellite images with latitude, longitude, and elevation attributes	Available precise-scale maps of about 100 meters for both mountainside and valley-side road locations	Base map from field reconnaissance on (a) abnormalities such as deformities in the ground or structure, and/or (b) historical geohazard signs including damages
	Maps (scale = 1:10,000 or more precise) covering the landscape ecosystem area of the road, the river or stream crossing, and the valley-side road locations endangered by flow-type geohazards—covering up to 200 square kilometers from the debris-flow-endangered point of the road, river or stream crossing point, or valley-side road location (Note: The area outside the 200-square-kilometer landscape ecosystem exceeds the applicable limit for simple peak flow rate calculation. Also, there is no possibility of debris flow directly hitting the target location from outside this 200-square-kilometer area.)	Extraction of information on the landscape ecosystem area's geographical features to calculate the peak flow rate of flow-type geohazards (debris or earth flow, flood) Identification of flow-type geohazard outbreak source locations that are unstable or have the potential for slope failure (fall, collapse, or slide) and moving into the waterway to become potential debris or earth flow (Note: Free satellite images are applicable for the required purpose.)
Rainfall data	Data from the nearest rainfall station, preferably within the landscape ecosystem area of the road location	Hydrological calculation to determine peak flow rate of flow-type geohazards for different return periods (occurrence probability in years)
Actual measure of river flow rate (unit: cubic meters per second) and flow speed (unit: meters per second) for different flood return periods at several points of the river for flow-type geohazards affecting the subject road location	Simple rainfall-concentrated flow rate formula applied to small landscape ecosystem areas between less than 40 square kilometers and 200 square kilometers (Note: The actual flow rate for a river whose landscape ecosystem area exceeds 40 square kilometers is preferably obtained.)	Calibration of hydrological calculation to determine the peak flow rate of flow-type geohazards for different return period (occurrence probability in years)
Specific discharge curve and specific discharge for different return periods for landscape ecosystem area	Specific discharge = flow rate of the river (unit: cubic meters per second per square kilometer)	Hydrological calculation to determine peak flow rate of flow-type geohazards for different return periods (occurrence probability in years)

The Consultant's proposal should describe the detailed methodologies for the engineering investigation of the hazard-prone road locations, including the surrounding areas. The proposed investigation plan is subject to the approval of the Client. The general tasks included in the engineering investigation are as follows.

The Client should note the minimum steps to be undertaken based on the type of geohazard under investigation. This may involve contour mapping, geological mapping, hydrological modeling, soil testing, surveys, and so on. The following sections are provided as an example of requirements, which may be deleted or added to as appropriate.

3.2.1 Topographical Contour Mapping

The engineering investigation includes the preparation of topographical contour maps and longitudinal-section or cross-section of landform (ground surface elevation) for the design (diminishing scale = 1:100 to 1:5,000) depending on the size of the hazard for a location.

3.2.2 Engineering Geological Mapping and Section Profiling

Engineering geological maps and road section profiles using engineering geological information are to be prepared to cover an area extending about 100 meters from both the road mountainside and valley side. The mapping shall be expanded to ensure full coverage of any known geohazards (with a buffer of 100 meters) where these extend beyond the 100-meter guidance.

When dealing with debris-flow geohazards, the mapping will need to extend to cover an area sufficient to capture the potential debris-flow field.

In the engineering geological maps, the following geohazard-related topographical features are drawn:

- Existing collapsed area (no vegetation, accumulated collapsed material)
- Sliding area (cliff of sliding head or sliding mass)
- Talus deposit area
- Distribution area of stones or boulders (rockfall deposit, debris flow deposit)
- River erosion formation on the riverside cliff
- Vegetation cover and small tributaries (such as gully erosions and so on)
- Bedrock-exposed area with rock types, weather, fractured condition, bedding plane, joint plain, fault plane, and shearing zone.

3.2.3 Preliminary Hydrological Analysis for Flow-Type Geohazard

The preliminary hydrological analysis should be planned before conducting the field hydrological investigation for the flow-type geohazard (earth or debris flow, flooding, river erosion). A preliminary analysis uses available weather data (precipitation and temperature) and geographical and vegetation information in the landscape ecosystem area of the hazard-prone road location.

The preliminary hydrological analysis includes the following calculations:

- ***Hydrological calculation.*** The outputs of the hydrological calculations are (a) the flood volume or debris or earth flow at the road's river- or stream-crossing points; or (b) the depth of flooding on a road location, obtained by inputting several return periods (occurrence probability in years) of rainfall and thawing water.
- ***Flow-rate calculation.*** The flow rate of the river adjacent to the road, bridge abutments, or piers

is calculated by inputting several return periods (occurrence probability in years) of rainfall and thawing water data.

- ***Scouring prediction calculation.*** Scouring prediction depths of the river adjacent to the road, bridge abutments, or piers are calculated by inputting several return periods (occurrence probability in years) of rainfall and thawing water.

3.2.4 Soil and Rock Mass Investigation

The soil and rock mass investigation would provide an accurate understanding of the geohazard property and foundation for the structural measures. Field reconnaissance, subsurface drilling, test pits and trenches, geophysical prospecting, in situ tests, and laboratory tests may be used. The evaluation is conducted by the classification of soil types and rock-crack density or weathering. The engineering properties of strength and seepage permeability shall be evaluated. The density and directionality pattern of the discontinuities (such as joints) of a rock mass shall be evaluated.

3.2.5 Slope Stability Calculation for Slide-Type Geohazard

The “safety factor” is the resistance force against instability divided by the instability-causing force. A safety factor greater than 1.0 indicates that the slope is stable—although with no margin of error. The Consultant should provide a report on the method used for the detailed calculation procedure and input data as well as the justification. The calculation results shall be provided to the Client.

3.2.6 Monitoring of Precipitation and Geohazard Situation

Where required, the Consultant shall develop a plan for the installation of devices to monitor precipitation, river levels, and geohazards. This plan shall be costed and submitted to the Client for consideration, along with advice on what assumptions will need to be made (and the consequence of these) if the data are not available.

Devices for monitoring precipitation and the geohazard situation are to be installed upon Client’s approval.

3.3 Concept Designs

Based on the understanding of the cause of the failure determined from the aforementioned investigations, the Consultant shall identify a minimum of five test scenarios (TS) of different-magnitude events that could reasonably occur at the Project Site over the next 50-year period. The Consultant is to provide a probability of each TS occurring.

These TS may range from different rainfall events for flooding-based failures to different-magnitude earthquakes that may have triggered mass land movement. These TS will be used to assess the performance of the Concept Designs in terms of the resilience of the road network. Where the Project Site is within a length of road where similar failures are known to have occurred, the Consultant shall assess what improvement the various options offer to overall network resilience in addition to the improved resilience at the Project Site. (Improving the resilience at the Project Site may make little difference to network resilience if multiple other similar failures are untreated, or if many alternative routes exist.)

A range of Concept Designs shall be developed, including

- Maintenance-only solutions (that is, no major structural investments);
- Low-cost (often vegetation-based) solutions to stabilize the ground above or below the road; and
- Permanent structural solutions.

For each Concept Design and TS, the Consultant is (a) to provide simple drawings (minimum of plan and elevation) along with photographs of similar solutions implemented elsewhere to illustrate the proposed solutions; and (b) to estimate the following:

- Initial construction costs and a basic construction methodology
- Annual maintenance costs over a period of at least 30 years
- Annual operational costs over a period of at least 30 years
- Decrease in RUCs (compared with the maintenance-only solution) incurred by reducing the requirement for traffic diversion during road closures, assuming the rest of the network has 100 percent resilience to all TS
- Decrease in RUCs (compared with the maintenance-only solution) incurred by reducing the requirements for traffic diversion during road closures, assuming other similar sites on the network are not remediated.

Based on the above, the Consultant is to provide a recommendation to the Road Authority on the preferred solution. The Consultant shall recommend any further investigations (If any) that need to be completed to enable the Detailed Design to occur along with the consequence of not having such information.

The findings from this phase of the work will be reported to the Road Authority and presented in a workshop session. The Road Authority will subsequently advise the Consultant on the approved preferred solution to take forward to the Detailed Design.

3.4 Preparation of Detailed Design

Based on the preferred option selected by the Road Authority, the Consultant shall complete the Detailed Design. The Detailed Design comprises the drawings and documents for the tender of the construction contract, including the following:

- Results of the additional engineering investigation as approved by the Road Authority
- Updated design conditions and considerations after additional engineering investigations and monitoring
- Updated design calculation result(s) (for example, slope stability calculation or hydrological calculation for controlling the peak flow rate)
- Proposed additional investigations and monitoring during construction
- Detailed structural measure drawings (plan layout, longitudinal profile, cross-section layout, and detailed drawing of the structure)
- Detailed quantity estimates of the construction work and materials
- Detailed bill of the estimated costs
- Detailed maintenance plan and estimate of annual maintenance cost
- Net present value (NPV) and economic internal rate of return (EIRR) calculations
- Social and environmental impacts of the preferred option
- Recommended approach for the construction (including any temporary road diversions); contracting model (measure and value, lump sum, design-build, and so on); and risk analysis (qualitative and/or quantitative as appropriate) along with who should carry the risk (Client or Contractor).

3.5 Contract Document Preparation

[This phase may not be required and can be deleted if the Road Authority does not require it.]

The Consultant shall prepare all contract documentation necessary to enable the procurement of the physical works to occur. This shall include, as a minimum,

- Draft advertisement wording of the tender;
- All tender documents;
- Draft maintenance and operational manuals for the design (to be finalized upon completion of the works to reflect any variations made during construction); and
- Tender evaluation forms for use by the Road Authority.

[If the following is required, then it will need to be added in.]

Support for the tender process (preparing draft answers to questions, participating in the tender evaluation, and so on) shall be subject to agreement with the Road Authority.

4 DELIVERABLES

All deliverables shall be provided first as a draft, and after Client's feedback shall be submitted in final form. Unless otherwise directed, the acceptance of each deliverable by the Client shall be treated as a contract hold point. The Client may request a workshop on any of the deliverables once they have had time to review the Draft Final Report.

4.1 Inception Report

The Consultant shall show an understanding of the background and the objective of the Work, confirm the contents of the Work (tasks), and prepare a work plan with methodology in the Inception Report (IR) submitted to the Client.

4.2 Engineering Investigation Report

An Engineering Investigation Report, covering all aspects of the investigation into the cause of failure, shall be prepared. GIS shape files shall be provided in electronic format, ready for loading into the Client's GIS system.

4.3 Concept Designs

A Concept Designs Report covering all aspects of the concept design phase shall be provided to the Client for review and approval.

4.4 Contract Documentation

4.5 Final Report

The Consultant shall prepare a Draft Final Report that includes all the results of the tasks as well as the Manual for Promotion of Road Disaster Awareness and Partnership. The Draft Final Report shall be submitted to the Road Authority, with a subsequent workshop arranged by the Consultant to present the findings and recommendations to the Road Authority. The workshop shall take place 10 working days after submission of the Draft Final Report, and the Road Authority will determine which (if any) of the stakeholders are to be invited to the workshop.

The Consultant shall prepare a Final Report that revises and updates the contents of the Draft Final Report on the basis of the Client's comments on the Draft Final Report and during the workshop.

5 SCHEDULE

[Note that the timeline should be revised to reflect the scale of the project. The following is for a medium-size geohazard, where the Consultant does not need to undertake long-term monitoring to derive design parameters. For small, isolated sites, this process may be as short as three to four months, while the process for large-scale failures may exceed one year in duration.]

This section sets forth the planned schedule of the tasks, their descriptions, and milestones such as the delivery times of all reports. All tasks shall be completed within 180 days after contract effectivity, according to the schedule outlined below. In addition, the duration and contents of the Consultant's tasks may be changed depending on the size of the project or requests from the Client.

- Submission of the Inception Report: within 30 days after contract effectivity. The Consultant shall prepare an inception report (IR) (refer to Sections 3.1 and 4.1) comprising (a) table of contents, (b) methodologies, and (c) schedule of the preliminary investigation. Copies of the IR shall be delivered to the Client. The Consultant shall present and discuss the contents of the IR to the Client.
- Submission of the Engineering Investigation Report: within 45 days after contract effectivity. See the content requirements outlined earlier in Sections 3.2 and 4.2.
- Submission of the Concept Designs Report: within 60 days after contract effectivity. See the content requirements discussed earlier in Section 3.3.
- Submission of the Detailed Design Report: within 60 days after notification of the preferred option by the Road Authority. The Consultant shall prepare the Detailed Design Report comprising all the results of the Work (discussed earlier in Section 3.4) and submit the same to the Client. The Consultant shall present and discuss the contents of the Draft Final Report to the Client and collect all comments from the Client.
- Submission of contract documentation: within 30 days after approval of the Detailed Design Report by the Road Authority.
- Submission of the Final Report: within 10 days after approval of contract documentation. The Consultant shall prepare the Final Report covering all aspects of the project. The reports noted above may be used as Annexes to the Final Report.

6 PROFESSIONAL SKILLS AND EXPERIENCE REQUIRED

The consultant's team will include qualified personnel with extensive experience in geotechnical engineering, hydraulic engineering, risk assessment, civil engineering, and traffic modeling. The consulting firm shall have sufficient qualified personnel and resources, including international technical expertise and advisers, to provide all the necessary professional, technical, and expert services required to accomplish all the services described above within the prescribed time.

The consultant shall assemble a team for undertaking the scope of work and task described above. In responding to the ToR, consultancy organizations will provide curricula vitae, a description of roles and responsibilities, and a written statement of exclusivity and availability of key experts who will be working on the project.

Consulting firms may form joint ventures or associations with other consulting firms to enhance their capabilities, strengthen the technical responsiveness of their proposals, make available bigger pools of experts, and enhance the value and quality of their services. The following key personnel (whose experience and responsibilities are briefly described) will be considered in the evaluation of the technical proposals. Other expertise as required for the services to be rendered should be included as necessary and to reflect the Consultant's responsiveness to the ToR.

[The Client will need to review these inputs in the context of the nature of the road failure that is being investigated. Some expertise may not be required, or others may need to be added in.]

It is estimated that this project will require 22 person-months from the team and will be completed within a period of 10 months. A list of suggested key personnel to be deployed by the Consultant, with appropriate minimum person-months of each as per Client's assessment, is shown in Table A.4.2. However, the Consultant can make their own assessment of the required composition and man-months for the key personnel and the phasing of their mobilization. The adequacy of the proposed composition will be assessed in the context of the proposal.

Table A.4.2 Estimated Input of Key Professional Staff

No.	Position	Person-months
1	Team leader or project manager	7
2	Geotechnical specialist	4
3	Hydraulic engineer	4
4	Civil engineer	4
5	Transport economist or traffic modeler	3
Total estimated key staff person-months		22

The person nominated as the team leader or project manager may also be nominated for any of the other roles.

The minimum qualifications and experience of key professional staff are summarized in Tables A.4.3–A.4.7. However, the Consultant may propose an effective team considered to be the most suitable for carrying out the project. The technical proposal must outline why the proposed composition of the team is considered capable and most suitable. In particular, it is noted that many of the outputs require the use of GIS systems (ArcGIS), and the Consultant is to ensure that such skills exist within the team.

Table A.4.3 Qualifications and Skills of Team Leader or Project Manager

Qualifications and skills	Minimum of a master's degree in civil or highway engineering, computer science or information and communication technology (ICT), or a related topic, or equivalent professional experience of at least 15 years Fluency in English <<add other language as required>> language, both written and oral
General professional experience	At least 10 years of professional engineering experience
Specific professional experience	• Proven leadership and people management skills, including the ability to establish and maintain effective working relationships in an international multicultural working environment • Experience regarding work activities in transitioning and low- and middle-income countries • Experience in providing training or knowledge transfer to Client staff preferred • Minimum of 10 years' experience covering at least one aspect of the activities within this ToR (geotechnical, hydraulics, risk assessment, and so on)
Key responsibilities	• Provide overall management of all project activities • Coordinate and supervise the consultancy team and serve as the primary point of contact with the Client • Ensure high-quality deliverables • Lead the review and updating of the risk-based framework

[Amend, add additional and use as appropriate for the nature of the geohazard under investigation.]

Table A.4.4 Qualifications and Skills of Geotechnical Specialists

Qualifications and skills	Minimum of a master's degree in civil, road, or geotechnical engineering or related topic, or equivalent professional experience of at least 10 years Fluency in English language, both written and oral
General professional experience	Expertise and experience in activities relating to life-cycle management of geotechnical assets
Specific professional experience	• At least 10 years of professional experience in areas relevant to this project • Understanding of landslide hazards and failure mechanisms of geotechnical assets • Understanding of risk-based evaluation methodologies preferred
Key responsibilities	Lead all geotechnical aspects of the assignment: develop land movement scenarios, estimate consequences, and so on

Table A.4.5 Qualifications and Skills of Hydraulic Specialist

Qualifications and skills	Minimum of a master's degree in civil, road, or geotechnical engineering or related topic, or equivalent professional experience of at least 10 years Fluency in English language, both written and oral
General professional experience	Expertise and experience in activities relating to life-cycle management of geotechnical and hydraulic assets
Specific professional experience	• At least 10 years of professional experience in areas relevant to this project • Understanding of hydraulic modeling of catchments, climate modeling, and impact on road infrastructure • Understanding of risk-based evaluation methodologies preferred
Key responsibilities	Lead all geotechnical aspects of the assignment: develop hydraulic scenarios, estimate consequences, and so on

Table A.4.6 Qualifications and Skills of Civil Engineer

Qualifications and skills	Minimum of a master's degree in civil, road, or geotechnical engineering or related topic, or equivalent professional experience of at least 10 years Fluency in English language, both written and oral
General professional experience	Expertise and experience in estimating the costs of highway works
Specific professional experience	• At least 10 years of professional experience in areas relevant to this project • Understanding of road damage caused by geohazards • Understanding of risk-based evaluation methodologies preferred
Key responsibilities	Lead all design elements

Table A.4.7 Qualifications and Skills of Transport Economist or Traffic Modeler

Qualifications and skills	Minimum of a bachelor's degree in a relevant field (engineering, economics, science, or the like) and equivalent professional experience of at least 10 years Fluency in English language, both written and oral
General professional experience	Expertise in the economic evaluation of road investment projects
Specific professional experience	At least 10 years of professional experience in areas relevant to this project
Key responsibilities	Undertake the economic evaluation of the proposed solutions, including the estimation of additional road user costs owing to diversion routes

7 ANNEX A.4.1: LIST OF ATTACHMENTS

[The following should either be provided as attachments to the ToR, or the location of such information should be provided in the ToR such as a website link]

- Attachment A.4.1.1: Location Map of the Hazard-Prone Road Locations
- Attachment A.4.1.2: Maps of Road Alignments Showing the Hazard-Prone Road Locations
- Attachment A.4.1.3: Attach additional information and data useful for the design to be added

APPENDIX A.5

Terms of Reference 5 (ToR 5)

DEVELOPMENT OF MANUAL FOR OPERATION AND MAINTENANCE FOR ROAD GEOTECHNICAL ASSETS, AND IMPLEMENTATION OF A ROAD GEOTECHNICAL ASSET MANAGEMENT INFORMATION SYSTEM (AMIS)

This ToR is for

1. The development of a stand-alone Manual for Operation and Maintenance for Road Geotechnical Assets. Many road authorities will have existing operations and maintenance manuals, in which case this ToR should be used to guide the development of the geohazard component of it—or as part of a review of the geohazard component of the existing manual.

2. The implementation of a risk-based road infrastructure asset management information system (AMIS), which in practice is likely to be the enhancement of an existing AMIS to capture additional data fields along with potential modification of decision support algorithms.

1 BACKGROUND

This box is to be deleted once the ToR is completed by the road authority.

Provide a paragraph or two on the background to this ToR. For example, is it part of a World Bank-funded technical assistance (TA) project or similar?

This terms of reference (ToR) is for the development of a Manual for the Operation and Maintenance of Road Geotechnical Assets ("O&M Manual"). It has been produced to align with the methodologies and approaches defined in the "Road Geohazard Risk Management Handbook." As per the Handbook, O&M activities include

- Routine maintenance of previously constructed measures;
- Monitoring of geohazards (either manually or through the use of automatic measuring devices, linked to automated warning systems); and
- Road closures to prevent injury before (or during) a geohazard event.

This ToR covers the <<Insert Road Authority Name>> (the "Road Authority") that is responsible for the development and operations and maintenance (O&M) of the <<Insert road hierarchy>> road network within <<Insert country and/or state name>>. The ToR covers all areas of operation within the Road Authority that reasonably affect road geohazard risk management from an O&M perspective. The development of the O&M Manual will necessitate consultation with a wide range of stakeholders as further elaborated on within this ToR.

The Road Authority notes the following observations regarding its own management of road geohazard risks and the associated risks that the road network is exposed to:

<<Replace following bullet points with relevant comments on the current status>>

- Government's role and stance regarding road geohazard risk management
- Is the work delivered using in-house resources, or is some outsourced to private sector consultants or contractors?
- Current status of road sector and road network development: for instance, well-developed road network, basic infrastructure
- Condition or characteristics of natural disasters: for instance, wide-scale flooding, mountain landslides
- Examples of road damage events by geohazards: for instance, in 2016 there was a major flood that xxx
- Needs for road geohazard risk management

- Current status of the road AMIS and associated tools: in particular, are any data relevant to geohazards already captured? Are geohazards captured in GIS systems already?

The following information shall be included in the background and then this box deleted:

- Current status of roads and related landscape
- The natural condition of the road section(s): climate, topography, geology, and so on
- The type of geohazards occurring on the road network
- Approach to road maintenance activities in the country: in-house force account; contracted out on short- or long-term contracts; input-, output-, or outcome-based contracts
- Current status of structural measures for road geohazard risk management
- Other information for the development of the Manual

The background should also provide an overview of the following to enable the consultant to understand the likely effort involved in developing good-practice O&M guidance:

- Related laws and regulations
- Technical standards
- Existing road maintenance manual
- Organization charts
- Ledgers of roads, geohazard locations, and road maintenance facilities (ideally all plotted on a map).

2 OBJECTIVES

There are two primary outputs to be delivered through this ToR:

- An O&M Manual for the management of road geohazards
- An asset management information system (AMIS) that appropriately addresses road geohazard risks.

The objective of the first part of the consultancy assignment is to create an O&M Manual that is of use in the day-to-day management of road geohazards and that has predefined responses (road closures, diversion routes, and so on) for known medium- to high-risk geohazard locations.

The objective of the second part of the assignment is to either enhance the existing AMIS (if one is in place) or to develop and implement a new AMIS (if one is not already in place) to yield a sustainable computerized, risk-based AMIS that will support effective decision making in prioritizing road infrastructure investment options at the strategic, tactical, and operational levels of asset management. This shall preferably be achieved by adding functionality (data fields or tables, analysis modules, reporting, and so on) to the existing road AMIS, rather than by implementing a stand-alone geohazard AMIS.

3 SCOPE OF WORK

3.1 Phase I: Inception Report

The Consultant shall understand the background and the objectives of this Work and describe as such in an Inception Report (IR). The IR shall, as a minimum, confirm contents of the Work (tasks), prepare a work plan, prepare an initial outline structure for the O&M Manual, and contain a summary of the current AMIS.

The Consultant shall collect existing data and information concerning the maintenance of roads and related facilities, including structural measures for geohazards, and summarize this within the IR. This will include items such as

- Related laws and regulations;
- Technical standards;
- Existing road operation and maintenance manuals;
- Organization charts; and
- Ledgers of roads, geohazard locations, and road maintenance facilities (ideally all plotted on a map).

Annex A.5.1 contains a nonexhaustive listing of information that the Road Authority believes to be relevant to this assignment; however, the Consultant shall exercise their judgment and expertise to determine which of those items listed require full review and also to seek out other information that is pertinent to this assignment.

<<This is only required if not already existing>>The Consultant is to develop a series of maps in ArcGIS format (or similar other formats as approved by the Road Authority) that illustrate the general nature of geohazards across the road network. These maps are not for the identification of specific locations of geohazards (for example, a landslide at KMxxx on road 123) but rather to illustrate the general location of different geohazard zones (for example, areas of high flooding risk, areas of high landslide risk).

All data that can be reasonably geolocated shall be mapped in geographic information systems (GIS) to visually understand where the geohazard risk is high, where geohazard awareness information has been provided, alternative routes if roads are closed, and so on.

3.2 Phase II: Project Concept Report

3.2.1 Objective 1: O&M Manual

The Consultant shall interview the people in charge of the road maintenance and geohazard risk management activities as well as key staff to understand the current conditions of the roads and the associated risks. The Consultant shall inspect a sample of the road network to observe maintenance practices that affect road geohazards. Current implementation mechanisms, the status of hazard monitoring, the number of available staff, budget issues, the condition of maintenance records, and information systems shall be studied.

The interviews will need to cover all levels of the road authority, including

- Head office staff responsible for overall O&M activities on the roads;
- Head office staff responsible for the development of standards and guidelines relevant to O&M (both general road O&M and geohazards);
- Regional staff responsible for prioritizing investments in their portion of the road network; and
- Physical works contractors (including external contractors) and those overseeing physical O&M activities.

The Road Authority will assist in facilitating meetings with the above, with the Consultant to clarify whether one-on-one or workshop-style sessions are required.

The Consultant shall arrange all the collected data and information and identify current problems in O&M of the road geohazard risk management activities.

The Consultant shall prepare a Project Concept Report, which shall describe the current approach to geohazard O&M management, the identified problems to be solved, and the plan of activities to develop the O&M Manual.

Any changes to the initial outline structure of the O&M Manual prepared as part of the IR shall be agreed upon with the Road Authority. It is quite possible, upon examination of the overall O&M documentation within the Road Authority, that rather than a stand-alone geohazard O&M Manual, an additional chapter(s) could be added to existing documentation—thereby creating a more comprehensive and integrated approach to road O&M. The Consultant shall advise on such options.

3.2.2 Objective 2: Geohazard AMIS Enhancement

The Consultant shall make recommendations as to how the existing AMIS (including any associated decision-support tools and reporting) should be modified to incorporate the risk-based management of road geohazards. In making recommendations, the Consultant is to consider which aspects of the existing decision-making process can (and should) be automated to include geohazard risks, and which aspects would be better approached through the flagging of road or bridge treatments as being in areas of geohazard risk for subsequent manual analysis.

For geohazards that rarely occur or that affect only a limited portion of the total road network, the Consultant is to advise whether activities beyond simply capturing the presence of a geohazard and the magnitude of any failure are warranted. Adding significant complexity to an AMIS for limited benefit is not good practice and is to be avoided.

It costs significant money to capture data and keep it up-to-date, and the costs of such investment relative to the overall benefits likely to be obtained shall be considered when making recommendations to the Road Authority. As a minimum, the AMIS is to capture or provide all data necessary to support the proposed O&M Manual.

Where the geohazard AMIS cannot be integrated into the existing AMIS, the Consultant is to recommend the appropriate technology platform and software to be used for the geohazard risk management.

The Consultant is to provide such detail as is necessary within the Project Concept Report to illustrate the proposed concept for each of the geohazard types under consideration.

3.3 Phase III: Delivery of Outputs

3.3.1 Objective 1: O&M Manual Development

The Consultant shall develop methodologies (or enhance existing methodologies) for road geohazard risk management in road O&M activities.

This task includes developing visual inspection methodologies for the range of geohazards, routine maintenance activities for existing structural measures (including drainage), operational activities for when geohazards occur, and hazard monitoring for early anomaly detection based on the results from the data collection during Phase I.

In developing the methodologies, the following should be considered:

- Basic road O&M policy and framework
- Implementation of road O&M mechanism(s)
- Combination with ordinary road O&M activities
- Combination with ordinary road patrol (daily and periodic inspections)
- Monitoring of the progress of deformation in road slope; structural measures; and/or road-crossing streams or rivers, bridge or culvert foundation erosion or scoring, and road riverside erosion or scoring
- Types and characteristics of structural measures and their maintenance checkpoints (for example, slope vegetation, debris clearing from check dams, and sediment clearing from drainage)
- Recording and keeping of maintenance activity records
- Need for seasonal road closures
- Emergency response, including the criteria and procedures for road closure, such as during inclement weather or other emergency situations.

The Consultant shall prepare the O&M Manual, describing the procedures for patrol and maintenance of the road geohazard structural measures. The procedures should

- Clearly define the frequency of patrols and inspections, the skill sets required to undertake the inspections, and any equipment necessary to undertake the patrols and maintenance safely (separating out the routine patrols by maintenance staff from those of specialized geotechnical or structural engineers);
- Contain all necessary inspection sheets for the range of geohazards, to ensure consistent recording of information;
- Define the conditions under which roads should be closed and who has authority to make such decisions;
- Define—for all roads in known moderate- to high-geohazard risk locations—the locations of road closures, detour routes, signage, and related activities (including the process for advising emergency services of closures); and
- Include draft service agreements or similar documents for the Road Authority to use for entering into an agreement with other stakeholders (notably, other road authorities that the detour routes may affect as well as emergency services) in relation to O&M activities.

3.3.2 Objective 2: Geohazard AMIS

[The Client will need to ascertain the software licensing arrangements for any existing AMIS in place. It may be that this ToR can go only so far in developing the logic and amendments needed to the existing AMIS, and the Client will need to separately engage the software vendor to make the changes.]

Based on the approved Project Concept Report, the Consultant is to develop the geohazard risk AMIS. The Consultant is to fully document all changes proposed to the existing AMIS, any new decision-making logic, and sample reporting formats.

All software shall be provided in both compiled and noncompiled (source code) form unless it is provided under a third-party license that makes such a requirement not possible. The Consultant shall prepare a user manual (or edit existing manuals) for all aspects of the geohazard AMIS implemented.

Upon completion of the AMIS, the Consultant is to collect and load data for a small sample of road geohazards to fully test all functions of the AMIS. The Consultant is to either (a) confirm with the Road Authority that all aspects of the AMIS are working as intended, or (b) advise of modifications required for the AMIS to yield appropriate outputs. This shall include the provision of sample outputs from the AMIS for review by the Road Authority.

Upon acceptance of the sample outputs, the Consultant is to complete the collection and loading of data for 100 kilometers of the Road Authority's road network. The Consultant and Road Authority shall agree on the roads to be included in this phase of the assignment. The Consultant is to report on the resources (time and equipment) needed to complete the collection and loading of the data for the 100 kilometers of roads, along with an estimate of the time to complete data collection and loading for the remainder of the road network.

For the initial 100 kilometers of roads, the Consultant is to demonstrate how the inclusion of geohazards has affected the resultant recommended road investment program.

3.4 Training

The Road Authority will nominate a maximum of 10 staff whom the Consultant is to train in all aspects of the project outputs. The Consultant shall ensure that these Road Authority staff are suitably able to train others in the use of the O&M Manual and enhanced AMIS. Training materials produced by the Consultant shall be provided to the Road Authority for use in subsequent training sessions, including in an editable format (for example, Microsoft PowerPoint).

The Consultant shall also separately train a maximum of two Road Authority staff in the maintenance of the AMIS software. This training is to cover the system architecture, source code, and related activities.

3.5 Final Workshop(s)

A Final Workshop shall be held to present and explain the O&M Manual to the Road Authority's staff and key stakeholders. The Consultant shall present the practical methodologies in the proposal to the Road Authority. The Consultant shall also train the relevant parties in the use of the O&M Manual and the geohazard AMIS.

In agreement with the Road Authority, more than one such workshop or training session may be necessary to ensure geographic coverage of the Road Authority's area of responsibility.

4 DELIVERABLES

All deliverables shall be provided first as a draft, and after Client's feedback shall be submitted in final form. Unless otherwise directed, the acceptance of each deliverable by the Client shall be treated as a contract hold point. The Client may request a workshop on any of the deliverables once they have had time to review the Draft Final Report.

4.1 Phase I: Inception Report

The Consultant shall understand the background and the objectives of this Work and describe as such in an Inception Report (IR). The IR shall, as a minimum, confirm contents of the Work (tasks), prepare a work plan, prepare an initial outline structure for the O&M Manual, and contain a summary of the current AMIS.

4.2 Phase II: Project Concept Report

The Consultant shall prepare a Project Concept Report, which shall describe

- The current approach to geohazard O&M management, the identified problems to be solved, and the plan of activities to develop the O&M Manual; and
- The proposed approach to implementing geohazard risk management into the AMIS.

4.3 Phase III: Outputs

The consultant shall provide the following:

- O&M Manual developed in accordance with this ToR
- Full documentation of all proposed changes to the existing AMIS, any new decision-making logic, and sample reporting formats
- Any software developed for the AMIS.

4.4 Final Report

The Consultant shall prepare the Draft Final Report, including all the results of the tasks together with the O&M Manual. The Draft Final Report shall be submitted to the Road Authority, with a subsequent workshop arranged by the Consultant to present the findings and recommendations to the Road Authority. The workshop shall take place 10 working days after submission of the Draft Final Report, and the Road Authority will determine which (if any) of the stakeholders are to be invited to the workshop.

The Consultant shall revise and update the contents of the Draft Final Report by considering comments from the Road Authority and counterpart agencies. The O&M Manual and user manual for the AMIS shall also be finalized and included along with the Final Report.

4.5 Final Workshop(s)

A copy of all workshop materials shall be provided in both Microsoft PowerPoint and Adobe PDF formats for future use by the Client.

5 SCHEDULE OF TASKS

[All dates and timelines to be revised in light of current status of AMIS and effort required]

All tasks shall be completed within 180 days after contract effectivity according to the schedule outlined below. Note: The duration of the Consultant's tasks should be revised in consideration of the size of the road network (and hence the number of stakeholders) to be engaged.

- Submission of Inception Report: within 10 days after contract effectivity. The Consultant shall prepare an IR comprising the contents, methodologies, and a schedule for development of the O&M Manual. Copies of the IR shall be submitted to the Road Authority in electronic format plus one hard copy. The Consultant shall present and discuss the contents of the IR with the Road Authority.
- Submission of Project Concept Report: within 60 days after contract effectivity. Copies of the Draft Project Concept Report shall be delivered to the Road Authority in electronic format plus one hard copy. The Consultant shall present and discuss the contents of the Draft Project Concept Report with the Road Authority. The Consultant shall prepare the Final Project Concept within two weeks of receiving feedback on the draft from the Road Authority.

- Submission of Draft O&M Manual: within 90 days after submission of the final Project Concept Report. The Consultant shall prepare and submit the Draft O&M Manual for review by the Road Authority and those stakeholders selected by the Road Authority. The Consultant shall present and discuss the contents of the Draft O&M Manual with the Road Authority in a workshop-style setting including selected stakeholders. The Road Authority will be responsible for consolidating feedback on the Draft O&M Manual.
- Geohazard AMIS: within 90 days after submission of the final Project Concept Report. Achievement of this milestone is upon acceptance of the AMIS with the sample geohazard information loaded and outputs provided to the Road Authority.
- Collection of data on 100 kilometers of roads: within 60 days of completion of the Geohazard AMIS.
- Training: Provided according to the agreed-upon program between the Consultant and the Road Authority.
- Submission of Draft Final Report: within 10 working days after final training session. The Consultant shall prepare a Draft Final Report, comprising all of the results of the Work, for review by the Road Authority and those stakeholders selected by the Road Authority. The Draft O&M Manual and the AMIS user manual are to be submitted as stand-alone documents. The Draft Final Report shall be submitted to the Road Authority in electronic format plus one hard copy. The Consultant shall present and discuss the contents of the Draft Final Report with the Road Authority in a workshop-style setting including selected stakeholders. The Road Authority will be responsible for consolidating feedback on the Draft Final Report.
- Submission of Final Report: within 30 days after feedback on the Draft O&M Manual and Draft Final Report. The Consultant shall prepare the Final Report and Final O&M Manual, revising the contents based on the comments from the Road Authority. The Consultant shall submit all the deliverables, including the Final Report, to the Road Authority in both electronic format and five hard copies.

All reports shall be in the language(s) of English and <<enter a second language if required>>. In addition to the specified number of hard copies, electronic submissions shall be in the following formats:

- Draft reports need only be in PDF format, with permissions set to enable copying of contents and insertion of comments.
- Final reports are to be provided in both PDF format and in an editable format such as Microsoft Office (Word, Excel, and so on); ArcGIS; or another approved format.

6 PROFESSIONAL SKILLS AND EXPERIENCE REQUIRED

The Consultant's team will include qualified personnel with extensive experience in road operation and maintenance, software development, asset management, geotechnical engineering, hydraulic engineering, risk assessment, civil engineering, and related geohazard management. The consulting firm shall have sufficient qualified personnel and resources, including international technical expertise and advisers, to provide all necessary professional, technical, and expert services required to accomplish all the services described above within the prescribed time.

The Consultant shall assemble a team for undertaking the scope of work and task described above. In responding to the ToR, consultancy organizations will provide curricula vitae, description of roles and responsibilities, and a written statement of exclusivity and availability of key experts who will be working on the project.

Consulting firms may form joint ventures or associations with other consulting firms to enhance their capabilities, strengthen the technical responsiveness of their proposals, make available bigger pools of experts, and enhance the value and quality of their services. The following key personnel (whose experience and responsibilities are briefly described) will be considered in the evaluation of the technical proposals. Other expertise as required for the services to be rendered should be included as necessary and to reflect the consultant's responsiveness to the ToR.

It is estimated that this project will require 22 person-months from the team and will be completed within a period of 10 months. A list of suggested key personnel to be deployed by the Consultant with appropriate minimum person-months of each as per Client's assessment is shown in Table A.5.1. However, the Consultant can make their own assessment for the required composition and person-months for the key personnel and the phasing of their mobilization. The adequacy of the proposed composition will be assessed in the context of the proposal.

Table A.5.1 Estimated Input of Key Professional Staff

No.	Position	Person-months
1	Team leader or project manager	7
2	O&M specialist	5
3	Asset management specialist	4
4	Civil engineer	2
5	Software developer	4
Total estimated key staff person-months		22

The person nominated as the team leader or project manager role may also be nominated for any of the other roles.

The minimum qualifications and experience of key professional staff are summarized in Tables A.5.2–A.5.7. However, the Consultant may propose an effective team considered to be the most suitable for carrying out the project. The technical proposal must outline why the proposed composition of the team is considered capable and most suitable. In particular, it is noted that many of the outputs require the use of GIS systems (ArcGIS), and the Consultant is to ensure that such skills exist within the team.

Table A.5.2 Qualifications and Skills of Team Leader or Project Manager

Qualifications and skills	Minimum of a master’s degree in civil or highway engineering, computer science or information and communication technology (ICT), or a related topic, or equivalent professional experience of at least 15 years Fluency in English <<add other languages as required>> language, both written and oral
General professional experience	At least 10 years of professional engineering experience
Specific professional experience	• Proven leadership and people management skills, including the ability to establish and maintain effective working relationships in an international multicultural working environment • Experience regarding work activities in transitioning or low- and middle-income countries • Experience in providing training or knowledge transfer to Client staff preferred • Minimum of 10 years’ experience covering at least one aspect of the activities within this ToR (geotechnical, hydraulics, risk assessment, and so on)
Key responsibilities	• Provide overall management of all project activities • Coordinate and supervise the consultancy team and serve as the primary point of contact with the Client • Ensure high-quality deliverables • Lead the review and updating of the risk-based framework

Table A.5.3 Qualifications and Skills of O&M Specialist

Qualifications and skills	Minimum of a master’s degree in civil engineering or a related topic, or equivalent professional experience of at least 10 years Fluency in English language, both written and oral
General professional experience	Expertise and experience in operation and management of road networks with geohazard issues
Specific professional experience	• At least 10 years of professional experience in areas relevant to this project • Understanding of geohazards • Ability to consult with stakeholders • Development of O&M manuals • Identification and analysis of diversion routes
Key responsibilities	Lead the development of the O&M Manual for Road Geotechnical Assets

Table A.5.4 Qualifications and Skills of O&M Specialist

Qualifications and skills	Minimum of a master's degree in civil engineering or a related topic, or equivalent professional experience of at least 10 years Fluency in English language, both written and oral
General professional experience	Expertise and experience in operation and management of road networks with geohazard issues
Specific professional experience	• At least 10 years of professional experience in areas relevant to this project • Understanding of geohazards • Ability to consult with stakeholders • evelopment of O&M manuals • Identification and analysis of diversion routes
Key responsibilities	Lead the development of the O&M Manual for Road Geotechnical Assets

Table A.5.5 Qualifications and Skills of Asset Management Specialist

Qualifications and skills	Minimum of a master's degree in civil engineering or related topic, or equivalent professional experience of at least 10 years Fluency in English language, both written and oral
General professional experience	Expertise and experience in road or bridge asset management
Specific professional experience	• At least 10 years of professional experience in areas relevant to this project • Understanding of asset management practice (as opposed to a specific asset management information system) • Working knowledge of <<Name the current AMIS in use>> preferable • Understanding of risk-based evaluation methodologies preferred
Key responsibilities	• Lead discussions on how to integrate the geohazard risk management requirements into the overall asset management processes in place within the Road Authority • Ensure that the benefits of the added complexity are justified

Table A.5.6 Qualifications and Skills of Civil Engineer

Qualifications and skills	Minimum of a master's degree in civil, road, or geotechnical engineering or related topic, or equivalent professional experience of at least 10 years Fluency in English language, both written and oral
General professional experience	Expertise and experience in estimating the costs of highway works
Specific professional experience	• At least 10 years of professional experience in areas relevant to this project. • Understanding of road damage caused by geohazards • Understanding of risk-based evaluation methodologies preferred
Key responsibilities	Lead all design elements

Table A.5.7 Qualifications and Skills of Software Developer

Qualifications and skills	Minimum of a bachelor's degree in a relevant field and equivalent professional experience of at least five years Fluency in English language, both written and oral
General professional experience	Expertise in the development of software
Specific professional experience	• Experience in developing software based on an << Specify the database platform to be required. Might be Access, SQL, Oracle etc.>> database • Experience in GIS applications • Experience in producing user manuals and delivering training on software use • Experience in road asset management information systems preferred
Key responsibilities	Undertake all software development tasks

7 ANNEX A.5.1: LISTING OF RELEVANT INFORMATION

- Attach a listing of information and data useful for the Manual for Operation and Maintenance for Road Geotechnical Assets such as location maps, lists of technical standards to be applied, regulations and laws, etc. to be added by the Road Authority.
- Attach a listing of information and data useful for the AMIS development such as user manuals of the existing AMIS, sample reports, analysis methodologies etc.

APPENDIX A.6

Terms of Reference 6 (ToR 6)

DEVELOPMENT OF EMERGENCY INFORMATION SYSTEM

Ideally the development of an emergency information system (EIS) would be based around the full scope of emergencies that a road authority deals with, and not just be confined to geohazard emergencies.

In the absence of a broader EIS being in place, this ToR has been developed to develop an EIS with a geohazard focus. Alternatively, the contents of this ToR could be used to develop a ToR for an overall EIS covering all emergency events.

1 BACKGROUND

This box to be deleted once ToR is completed by the Road Authority.

Provide a paragraph or two on the background to this ToR. For example, is it part of a World Bank-funded technical assistance (TA) project or similar?

This terms of reference (ToR) is for the development of an Emergency Information System (EIS). It has been produced to align with the methodologies and approaches defined in the "Road Geohazard Risk Management Handbook."

This ToR covers the <<Insert Road Authority Name>> (the "Road Authority") that is responsible for the development, operations, and maintenance of the <<Insert road hierarchy>> road network within <<Insert country and/or state name>>.

The following roads ("The Roads") are to be covered by the EIS:

<<Insert a listing of roads, or road sections, and a map showing the roads>>

<<Provide commentary (or a map) on the types of geohazard risks that the roads are exposed to>>

- Current situation of the selected geohazard-prone road subsection(s)
- Natural condition of the road subsections: climate, topography, geology, and so on
- Current traffic-related problems in selected road sections (for example, accidents, historical geohazard road damage events, and geohazards)
- Current situation on the collection of road traffic condition information (road closure), the road geohazard situation, warnings on abnormal weather, and early warning procedures regarding road conditions
- Other useful information for the project

The Road Authority notes the following observations with regard to its current EIS (or similar) capabilities:

<<Replace following bullet points with relevant comments on the current status>>

- Is any EIS currently in place?
- Are any information and communication technology (ICT) standards or restrictions in place?
- Are there any agreed-upon data standards in place or restrictions on where data can be stored?

2 OBJECTIVE

The objective of the proposed Work is to develop the Emergency Information System (EIS) on road traffic conditions for, among other things, early warning and precautionary road closure for the road sections and geohazard-prone subsections of The Roads. Although the solution developed is to be implemented on the aforementioned Roads, the solution should be readily deployable to other portions of the road network and be fully integrated (or compatible) with existing information and communication technology (ICT) solutions used by the Road Authority.

The objective emphasizes not only advanced ICT but also institutional coordination mechanisms (police, subnational or local government, rescue agency, meteorological agency, and landform ecosystem management organization) and communication with road users, communities, and residents along the subject Roads. The EIS shall collect, share, and disseminate emergency information and data to (a) support road management authorities' operations and maintenance activities, and (b) provide emergency information and early warnings to road users, residents, and commercial establishments along the subject roads.

3 SCOPE

The scope of this assignment is limited to the definition of all aspects of the EIS, documenting of procedures, and similar activities. The scope specifically excludes the installation of hardware or software to implement the recommendations.

4 TASKS, METHODS, AND DELIVERABLES

The tasks, methods, and deliverables for the required technical assistance services are as follows in Section 4.1 ("Phase I"), Section 4.2 ("Phase II"), and Section 4.3 ("Phase III").

4.1 Phase I

4.1.1 Collection and Arrangement of Data and Information

The Consultant shall collect data and information on the development of the EIS for the Road Authority—for example, existing information systems; purposes, types, and contents of data; data sharing procedures; data utilization criteria or standards; early warning procedures and criteria, and the ICT infrastructure.

Annex A.6.1 contains a nonexhaustive listing of information that the Road Authority believes to be relevant to this assignment; however, the Consultant shall exercise their judgment and expertise to determine which of those items listed require a full review and also to seek out other information that is pertinent to this assignment.

<<This is only required if not already existing>>The Consultant is to develop a series of maps in ArcGIS format (or similar other format as approved by the Road Authority) that illustrate the general nature of geohazards across The Roads. These maps are not for the identification of specific locations of geohazards (for example, a landslide at KMxxx on road 123) but rather to illustrate the general locations of different geohazard zones (for example, areas of high flooding risk, areas of high landslide risk).

All data that can be reasonably geolocated shall be mapped using ArcGIS.

4.1.2 Interviews, Surveys, and Site Observation

The Consultant shall interview the relevant people in charge of road operations and maintenance for the target road sections as well as key staff to understand the current conditions of activities for collecting and sharing emergency information on the hazard-prone subsections. Furthermore, the Consultant shall check and validate the actual activities conducted by related staff. The Consultant shall collect and analyze information on current implementation mechanisms; the number of available personnel; budget issues; the condition of information and data storage; existing information systems; procedures; and their information system infrastructure for road conditions, including an early warning or precautionary road closure.

The Road Authority will assist in facilitating meetings with the above, with the Consultant to clarify whether one-on-one or workshop-style sessions are required.

4.2 Phase II

4.2.1 Development of Emergency Response, Early Warning, and Precautionary Road Closure Procedures

Based on the results of Phase I results and findings, the Consultant shall prepare and propose the revised, updated, or new emergency response activities as well as the early warning and precautionary road closure procedures to be performed by the Road Authority. The EIS is the tool aimed at assisting the Road Authority and its staff involved with road emergency activities.

The following shall be considered in the examination of the existing emergency response and early warning or precautionary road closure procedures:

- Types of hazards requiring emergency response, early warning, or precautionary road closure on The Roads
- Emergency response and early warning elements and procedures to be performed by the Road Authority
- Definition of information to be shared with road users and communities, residents, and commercial establishments along the roads
- Information or data flow and necessary functions for emergency response and early warning or precautionary road closure (collection, storage, analysis, judgment, information provision, sharing arrangements with third parties, and so on)
- Remote control of monitoring instruments such as rainfall gauges, ground displacement measuring devices, earth or debris flow detection devices, and flooding and road inundation monitoring devices
- Information or data transmission and reception system
- Improvement plan for the implementation of the emergency response and early warning process procedure and the required budget estimate
- Classification of emergency response activities and early warning and precautionary road closure methods as either (a) manual, analog, or human-based; or (b) ICT (automatic, digital, or computer-based)
- Required components that the EIS should have
- Plan for institutional and staff arrangement.

The following considerations shall be examined regarding early warning or precautionary road closure:

- The early warning should be closely connected to precautionary road closure.

- Designation of road sections for precautionary road closure shall be considered in the improvement plan. Preparation of criteria for the early warning or precautionary road closure is essential before developing the EIS.
- Execution of emergency, early warning, and precautionary road closure should be established to reach all road users and residents quickly and correctly.
- Cancellation of early warning or precautionary road closure needs to have defined criteria.

4.2.2 Basic Design of EIS (Automatic or Computerized System)

The Consultant shall develop the Basic Design of the EIS based on the identified requirements and the plan for emergency response and early warning to be used by the Road Authority. Diagrams of the EIS for The Roads shall be prepared and indicative costings (±30 percent) estimated.

The Basic Design shall enable

- Determination of the institutional coordination mechanisms between the Road Authority and other parties;
- Understanding of the functional capability of the different EIS components;
- Location of any signs and their functional capability (for example, free-form text versus fixed displays);
- Communication links between the various EIS components;
- Implementation of the EIS in a staged manner; and
- Interfaces with other systems that the Road Authority or stakeholders operate (or should reasonably operate).

The Basic Design of the EIS shall be submitted to the Road Authority, with a subsequent workshop arranged by the Consultant to present the findings and recommendations to the Road Authority. The workshop shall take place 10 working days after submission of the Basic Design, and the Road Authority will determine which (if any) of the stakeholders are to be invited to the workshop. The Road Authority will provide consolidated feedback on the proposed Basic Design of the EIS following the workshop.

4.2.3 Detailed Design of the Emergency Information System

The Basic Design shall be developed into a Detailed Design suitable for procurement of all components. The Detailed Design shall include

- Refined cost estimates (±20 percent) for developing or procuring hardware and software for the EIS;
- Recommendations on packaging of the various components to be procured;
- Recommendations on the best contractual model (including operational and maintenance arrangements) for the EIS, including both (a) the procurement of hardware and software, and (b) the procurement of the EIS as a service from external suppliers;
- Draft ToRs for the procurement of the hardware and software;
- Overall timeline (Gantt chart) showing the procurement, implementation, and testing of all components of the EIS; and
- Development of an associated operations manual for the EIS covering all aspects of the software and hardware, service agreements with stakeholders, and associated responses to be taken under emergencies.

The manuals for the operation and maintenance of the EIS shall be prepared and submitted to the Road Authority.

5 DELIVERABLES

5.1 Inception Report

The Consultant shall illustrate an understanding of the background and objective of the Work, confirm the contents of the Work (tasks), prepare a work plan, and submit the Inception Report (IR) to the Road Authority.

5.2 Analysis of Existing Conditions and Progress Report (I)

The Consultant shall arrange all the collected data and information and examine and identify current problems related to the EIS in the Road Authority offices as it pertains to The Roads. The Consultant shall prepare Progress Report (I), which shall include the current condition of related activities in the Road Authority offices and the identified problems to be solved. Progress Report (I) shall also include the plan of activities for Phase II to be submitted to the Road Authority.

5.3 Progress Report (II)

The Consultant shall prepare Progress Report (II), comprising all the results of the tasks in Phase II and the plan for Phase III activities.

Progress Report (II) shall be submitted to the Road Authority, with a subsequent workshop arranged by the Consultant to present the findings and recommendations to the Road Authority. The workshop shall take place within 10 working days after submission of Progress Report (II), and the Road Authority will determine which (if any) of the stakeholders are to be invited to the workshop. The Road Authority will provide consolidated feedback on the Progress Report (II) following the workshop.

5.4 Final Report

The Consultant shall prepare the Draft Final Report (comprising all the results of the tasks and the documents on the EIS) and submit it to the Road Authority.

The Consultant shall revise and update the contents of the Draft Final Report by considering the comments of the Road Authority. All the documents on the EIS shall also be finalized and included in the Final Report.

6 SCHEDULE OF TASKS

[Note: The duration of this ToR will be significantly affected by the current status of information systems within the Road Authority. If no current procedures or facilities are in place, then this ToR could well take more than one year to complete because there will need to be significant consultation with other government departments. Only a timeline for completion of Phases I and II is provided, as the timing of Phase III will be defined by the outputs for Phase II.]

All tasks associated with Phases I and II shall be completed within 180 days after contract effectivity, according to the schedule outlined below.

- Submission of Inception Report: within 10 days after contract effectivity. The Consultant shall prepare an IR comprising the contents, methodologies, and schedule of the tasks to be performed. Copies of the IR shall be delivered to the Road Authority. The Consultant shall present and discuss the contents of the IR with the Road Authority.

- Submission of Progress Report (I): within 45 days after contract effectivity. The Consultant shall prepare Progress Report (I) describing the contents noted in Section 5.2. Copies of Progress Report (I) shall be delivered to the Road Authority. The Consultant shall present and discuss the contents of the progress report with the Road Authority.
- Submission of Draft Procedures (as per Section 4.2.1): within 90 days after contract effectivity.
- Submission of Basic Design of the EIS (as per Section 4.2.2): within 120 days after contract effectivity.
- Submission of Detailed Design of the EIS (as per Section 4.2.3): within 30 days after receiving feedback on the Basic Design.
- Submission of Progress Report (II): within 60 days after receiving feedback on the Basic Design. The Consultant shall prepare Progress Report (II) describing the contents noted in Section 5.3. Copies of Progress Report (II) shall be delivered to the Road Authority. The Consultant shall present and discuss the contents of Progress Report (II) with the Road Authority.
- Timing for delivery of Phase III activities will be agreed upon with the Consultant as part of the review process of Progress Report (II).

7 PROFESSIONAL SKILLS AND EXPERIENCE REQUIRED

The Consultant's team will include qualified personnel with extensive experience in communications, geotechnical engineering, hydraulic engineering, risk assessment, civil engineering, and traffic modeling. The consulting firm shall have sufficient qualified personnel and resources, including international technical expertise and advisers, to provide all necessary professional, technical, and expert services required to accomplish all the services described above within the prescribed time.

The Consultant shall assemble a team for undertaking the scope of work and tasks described above. In responding to the ToR, consultancy organizations will provide curricula vitae, a description of roles and responsibilities, and a written statement of exclusivity and availability of key experts who will be working on the project.

Consulting firms may form joint ventures or associations with other consulting firms to enhance their capabilities, strengthen the technical responsiveness of their proposals, make available bigger pools of experts, and enhance the value and quality of their services. The following key personnel (whose experience and responsibilities are briefly described) will be considered in the evaluation of the technical proposals. Other expertise as required for the services to be rendered should be included as necessary and to reflect the Consultant's responsiveness to the ToR.

[The Client will need to review these inputs in the context of geohazards present on the network.]

It is estimated that this project will require 22 person-months from the team and will be completed within a period of 10 months. A list of suggested key personnel to be deployed by the Consultant with appropriate minimum person-months of each as per Client's assessment is shown in Table A.6.1. However, the Consultant can make their own assessment for the required composition and person-months for the key personnel and the phasing of their mobilization. The adequacy of the proposed composition will be assessed in the context of the proposal.

Table A.6.1 Estimated Input of Key Professional Staff

No.	Position	Person-months
1	Team leader or project manager	7
2	Communications specialist	6
3	Information communication technology (ICT) specialist	6
4	Geotechnical specialist	1
5	Hydraulic engineer	1
6	Civil engineer	1
7	Traffic modeler	1
Total estimated key staff person-months		23

The person nominated as the team leader or project manager may also be nominated for any of the other roles.

The minimum qualifications and experience of key professional staff are summarized in Tables A.6.2–A.6.8. However, the Consultant may propose an effective team considered to be the most suitable for carrying out the project. The technical proposal must outline why the proposed composition of the team is considered capable and most suitable. In particular, it is noted that many of the outputs require the use of geographic information systems (GIS) (such as ArcGIS), and the Consultant is to ensure that such skills exist within the team.

Table A.6.2 Qualifications and Skills of Team Leader or Project Manager

Qualifications and skills	Minimum of a master's degree in civil or highway engineering, computer science or information and communication technology (ICT), or a related topic, or equivalent professional experience of at least 15 years Fluency in English <<add other languages as required>> language, both written and oral
General professional experience	At least 10 years of professional engineering experience
Specific professional experience	• Proven leadership and people management skills, including the ability to establish and maintain effective working relationships in an international multicultural working environment • Experience regarding work activities in transitioning or low- and middle-income countries • Experience in providing training or knowledge transfer to Client staff preferred • Minimum of 10 years' experience covering at least one aspect of the activities within this ToR (geotechnical, hydraulics, risk assessment, and so on)
Key responsibilities	• Provide overall management of all project activities • Coordinate and supervise the consultancy team and serve as the primary point of contact with the Client • Ensure high-quality deliverables • Lead the review and updating of the risk-based framework

Table A.6.3 Qualifications and Skills of Communications Specialist

Qualifications and skills	Minimum of a bachelor's degree in a relevant field, and equivalent professional experience of at least 15 years Fluency in English language, both written and oral
General professional experience	At least five years of experience in communications related to transport projects
Specific professional experience	• Proven ability to take technical inputs from other team members and produce a high-quality communication document suitable for both technical and nontechnical reader • Experience with work activities in transitioning or low- and middle-income countries • Experience in writing communications documents for transport authorities (any mode) • Experience on at least one disaster awareness project in the past five years preferable
Key responsibilities	Define the overall messaging approach, creating the overall structure of communication materials (technical team to populate with relevant information), ensuring all communication materials and messages are fit for purpose

Table A.6.4 Qualifications and Skills of ICT Specialist

Qualifications and skills	Minimum degree in a relevant field, and equivalent professional experience of at least 15 years Fluency in English language, both written and oral
General professional experience	At least 10 years of experience in implementing information and communication technology (ICT) systems for transport networks
Specific professional experience	• Implementing ICT systems within road environments • Implementing ICT systems that have a high degree of resilience • Integrating information from external data sources to yield meaningful information to the end users • Deploying information systems across a range of platforms—from variable roadside signs to social media and direct messaging (for example, SMS texts)
Key responsibilities	Overall lead for the design and cost estimation of the ICT solution to be deployed

Table A.6.5 Qualifications and Skills of Geotechnical Specialists

Qualifications and skills	Minimum of a master's degree in civil, road, or geotechnical engineering or related topic, or equivalent professional experience of at least 10 years Fluency in English language, both written and oral
General professional experience	Expertise and experience in activities relating to life-cycle management of geotechnical assets
Specific professional experience	• At least 10 years of professional experience in areas relevant to this project • Understanding of landslide hazards and failure mechanisms of geotechnical assets • Understanding of risk-based evaluation methodologies preferred
Key responsibilities	Lead all geotechnical aspects of the assignment: develop land movement scenarios, estimate consequences, and so on

Table A.6.6 Qualifications and Skills of Hydraulic Specialist

Qualifications and skills	Minimum of a master's degree in civil, road, or geotechnical engineering or related topic, or equivalent professional experience of at least 10 years Fluency in English language, both written and oral
General professional experience	Expertise and experience in activities relating to life-cycle management of geotechnical assets
Specific professional experience	• At least 10 years of professional experience in areas relevant to this project • Understanding of hydraulic modeling of catchments, climate modeling, and impact on road infrastructure • Understanding of risk-based evaluation methodologies preferred
Key responsibilities	Lead all geotechnical aspects of the assignment: develop hydraulic scenarios, estimate consequences, and so on

Table A.6.7 Qualifications and Skills of Civil Engineer

Qualifications and skills	Minimum of a master's degree in civil, road, or geotechnical engineering or related topic, or equivalent professional experience of at least 10 years Fluency in English language, both written and oral
General professional experience	Expertise and experience in estimating the costs of highway works
Specific professional experience	• At least 10 years of professional experience in areas relevant to this project • Understanding of road damage caused by geohazards • Understanding of risk-based evaluation methodologies preferred
Key responsibilities	Develop cost estimates of damages to the road infrastructure for the scenarios under analysis

Table A.6.8 Qualifications and Skills of Traffic Modeler

Qualifications and skills	Minimum of a master's degree in civil, road, or geotechnical engineering or related topic, or equivalent professional experience of at least 10 years Fluency in English language, both written and oral
General professional experience	Expertise in the development of network-level traffic models
Specific professional experience	• At least 10 years of professional experience in areas relevant to this project • Development of origin–destination (O–D) models, from data survey techniques to model calibration and application • Detailed working knowledge of the traffic modeling platform proposed for use by the Consultant
Key responsibilities	Lead all aspects of the traffic modeling within this ToR

8 ANNEX A.6.1: LISTING OF RELEVANT INFORMATION

- Attach a listing of information and data useful for the EIS

APPENDIX A.7

Terms of Reference 7 (ToR 7):

DEVELOPMENT OF MANUAL FOR POSTDISASTER RESPONSE AND RECOVERY

Ideally the development of a Manual for Postdisaster Response and Recovery would be based around the full scope of disasters that a road authority deals with, and not just be confined to geohazard emergencies.

In the absence of a broader manual being in place, this ToR has been developed to develop a postdisaster response with a geohazard focus. Alternatively, the contents of this ToR could be expanded upon to develop a ToR for an overall response and recovery plan covering all disaster events.

1 BACKGROUND

This box to be deleted once ToR is completed by the Road Authority.

Provide a paragraph or two on the background to this ToR. For example, is it part of a World Bank-funded technical assistance (TA) project or similar?

This terms of reference (ToR) is for the development of a Manual for Postdisaster Response and Recovery after a geohazard event that leads to road damage. The Manual covers postdisaster needs assessment, emergency traffic regulation, and public notification as well as the subsequent recovery phase. Although nongeohazard events (such as major traffic accidents) may also result in the same responses, this ToR is limited to geohazard events.

This ToR has been produced to align with the methodologies and approaches defined in the "Road Geohazard Risk Management Handbook." As the Handbook discusses, postdisaster and recovery activities include the following:

- Preparedness
- Postdisaster
    - o Emergency inspection or postdisaster needs assessment
    - o Emergency traffic regulation and public notice
- Recovery
    - o Emergency recovery
    - o Repair
    - o Rehabilitation and reconstruction.

This ToR covers the <<Insert Road Authority Name>> (the "Road Authority") that is responsible for the development, operations, and maintenance of the <<Insert road hierarchy>> road network within <<Insert country and/or state name>>.

This box to be deleted once ToR is completed by the Road Authority.

The background shall include the following information:

- Current problems of road damage events (road traffic disturbance, road closure) in the country
- Past and current practice regarding emergency inspections or postdisaster needs assessment on roads or locally extensive damage or disaster events
- Past and current practice on urgent measures (for example, placement of barricades, road blocks, or sandbanks to arrest collapse, or covering the ground with impervious sheets to prevent water infiltration)
- Past and current practice on emergency traffic regulation to avoid road-user fatalities and casualties from dangerous, damaged road locations and successive geohazard events
- Past and current practice on response and recovery for road geohazards and geohazard risk management for damaged road locations
- Current status of institutional mechanisms for postdisaster response and recovery for road geohazards.

2 OBJECTIVE

The objective of the work is to develop the Manual for Postdisaster Response and Recovery. The Manual shall support the Road Authority and its staff (including external parties such as consultants, contractors, and emergency service personnel) in emergency inspection, postdisaster needs assessment, decision-making processes for emergency traffic regulation, and recovery when dealing with road damage or closure situations due to geohazards.

In the immediate aftermath of a disaster, there are often difficulties with communication lines, access to remote locations, and similar issues. The production of this Manual is expected to provide clarity and efficiency of processes during the postdisaster response phase such that even without communication, all parties know what is required to be done.

The Manual is also to cover postdisaster recovery, ranging from immediate emergency response to full restoration of the asset. In this regard, the Manual is not to provide guidance on which solution should be implemented but rather is to provide guidance on the arrangements that govern such decisions.

3 SCOPE

This ToR requires the Consultant to develop a Manual that will provide guidance to the Road Authority staff, consultants, contractors, and other key stakeholders during and after a disaster. Table A.7.1 defines the activities for this assignment. The Consultant shall refine this table and the associated definitions during the course of the assignment.

Table A.7.1 Classification of Activities for Postdisaster Response and Recovery

Category	Subactivity	Activity definitions
Preparedness	n.a.	• Development of an emergency preparedness and response plan • Preparedness training • Funding
Postdisaster response	Emergency inspection and postdisaster needs assessment	• Visual inspection and evaluation of road conditions, damages, and the local environment and social situation including landscape and slopes • Interviews with local road users and residents who are affected by the disaster on the road damages and recovery needs in the area • Assessment of recovery needs with associate cost estimates after road damage or closure due to geohazard events • Urgent measures to mitigate road damage expansion
	Temporary traffic management and public notice	• Temporary traffic management (or emergency traffic regulation) implemented by setting barricades to prevent harm to road users from damaged road portions (debris on roads, road deformation, road cutting, sinkhole, inundation, and so on) and to prevent road traffic from causing further damage to the road. Note that predisaster planning (see ToR 6) should have identified alternative routes, key institutions (hospitals, schools, and so on), and locations of road closure signage • Public notice of road closure or traffic disturbance due to road damage according to the agreed-upon communications plan (see ToR 6)
	Emergency response	• Emergency measures to secure safety to road users and reduce further asset damage • Elimination of road obstacles such as removal of fallen soils or placement of sandbags—without detailed investigation or design • Coordination with different sectors if service lines (gas, water, sewage lines, and the like) lie under the damaged road • Activation of funding for contingency emergency response
Recovery	Repair	• Normal maintenance work for road structures and facilities without detailed investigation or design, including localized pavement patching, reinstatement of roadside drainage, and so on • Original structure or function itself unchanged • Annual budget normally allocated
	Rehabilitation	• Construction work for recovery of damaged road • Applied to partially damaged road structures or facilities; may include a minor shift in road alignment • Temporary rehabilitation to secure traffic reactivation, including partial-width road recovery, temporary road detour alternatives, and temporary bridges • Full-scale rehabilitation to recover full road function, usually installing countermeasures for geohazard risk reduction • Special budget requested depending on damage severity
	Reconstruction	• Applied to roads, structures, or facilities that completely lost original function or were destroyed almost completely • Renewal or replacement of roads, structures, or facilities, incorporating risk assessment, planning, and design

3.1 Phase I

3.1.1 Collection and Arrangement of Data and Information

The Consultant shall collect available data and information on the development of postdisaster response and recovery for the Road Authority and relevant organizations or agencies (for example, existing manuals, protocols for activities during emergency situations, and any other relevant information and data).

Annex A.7.1 contains a nonexhaustive listing of information that the Road Authority believes to be relevant to this assignment; however, the Consultant shall exercise their judgment and expertise to determine which of those items listed require full review and also to seek out other information that is pertinent to this assignment.

<<This is only required if not already existing>>The Consultant is to develop a series of maps in ArcGIS format (or similar other format as approved by the Road Authority) that illustrate the general nature of geohazards across the road network. These maps are not for the identification of specific locations of geohazards (for example, a landslide at KMxxx on road 123) but rather to illustrate the general location of different geohazard zones (for example, areas of high flooding risk, areas of high landslide risk).

All data that can be reasonably geolocated shall be mapped to enable a visual understanding of locations where the geohazard risk is high; locations of emergency response depots; locations of emergency services (hospitals, ambulance, fire, police); alternative routes if roads are closed, and so on.

3.1.2 Interviews, Surveys, and Site Observation

The Consultant shall interview all the stakeholders in charge of road operations and maintenance as well as key stakeholders such as police, rescue agencies, local government, and community staff to understand the past and current activities during postdisaster situations affecting roads. The Consultant shall verify the activities undertaken by the related staff and seek to identify gaps or problems with current practices. The Consultant shall examine current implementation mechanisms; the number of available personnel; budget; the condition of postdisaster response and recovery; information and communication systems; procedures; and the infrastructure of their information and communication system for postdisaster response and response.

The Road Authority will assist in facilitating meetings with the above, with the Consultant to clarify whether one-on-one or workshop-style sessions are required.

3.1.3 Analysis of Existing Conditions and Progress Report

The Consultant shall tabulate and map all collected data and information as well as examine and identify current problems related to postdisaster response conducted by the corresponding authorities. These are to be included in the analysis to develop the Manual of Postdisaster Response and Recovery. The Consultant shall prepare a Progress Report comprising the current conditions of related activities conducted by the Road Authority and related organizations such as police and rescue agencies as well as the identified problems.

The Consultant shall recommend the best method of developing the Manual, either as a stand-alone document or through the expansion of an existing document.

The Progress Report shall also include the activity plan for Phase II. The Consultant will submit the Progress Report to the Road Authority.

3.2 Phase II

3.2.1 Development of Manual on Postdisaster Response and Recovery

Based on the results of the Phase I tasks, the Consultant shall develop the Manual for Postdisaster Response and Recovery, considering the following:

- Definition and grouping of the activities on postdisaster response and recovery to be performed by the Road Authority and staff (for example, see Table A.7.1)
- Methods for conducting postdisaster condition inspections, including the skills and equipment requirements as well as appropriate simplified data collection templates that can be used to provide a rapid assessment of the asset condition for initial decision making
- Protocols for the postdisaster response and recovery (preparation of decision trees) by considering possible or past disaster situations, including who makes what decisions regarding road closures and where to locate the emergency response control center with what equipment (for example, emergency generator, drawings, satellite phone, and so on)
- Formulation of the implementation mechanisms for postdisaster response and recovery, including (a) establishment of partnerships with local consultants and contractors for the emergency response and recovery; (b) consideration of how existing contracts should be amended to ensure that the response to emergency events is within the scope of the contract activities; (c) suggested payment mechanisms (commonly a schedule of rates); and (d) mechanisms for the Road Authority to secure funding for immediate response and recovery
- Recommendation of emergency supplies to be available in the Road Authority offices (for example, construction materials, spare parts, machinery, water, food, and fuel) under a few different disaster scenarios, and whether such supplies are warranted year-round or seasonally
- Development of draft contractual wording that the Road Authority can incorporate into existing or future road contracts to better respond to emergency events
- Draft service agreements for use in agreement processes between the Road Authority and external parties covering aspects from information sharing to the access of others' facilities, disposal of waste materials, and related matters
- Postdisaster review procedures to enable continuous improvement of the Manual and associated processes.

3.3 Workshop(s)

A workshop shall be held to present and explain the Manual to the Road Authority's staff and key stakeholders. The Consultant shall present practical methodologies in the proposal to the Road Authority. In agreement with the Road Authority, more than one such workshop may be necessary to ensure geographic coverage of the Road Authority's area of responsibility.

4 DELIVERABLES

The deliverables of the required technical assistance services are as follows in Section 4.1 ("Phase I") and Section 4.2 ("Phase II").

4.1 Phase I

4.1.1 Inception Report

The Consultant shall understand the background and the objective of this Work, confirm contents of the Work (tasks), prepare a work plan as the Inception Report (IR), and submit it to the Road Authority.

4.1.2 Collection and Arrangement of Data and Information

All data that have been mapped shall be supplied to the Client in geographic information system (GIS) shapefiles ready for importing into the Client's GIS.

4.1.3 Analysis of Existing Conditions and Progress Report

The Consultant shall prepare a Progress Report comprising the current conditions of related activities conducted by the Road Authority and related organizations such as police and rescue agencies as well as the identified problems.

The Consultant shall recommend the best method of developing the Manual—as a stand-alone document or through the expansion of an existing Client's document.

The Progress Report shall also include the activity plan for Phase II. The Consultant will submit the Progress Report to the Road Authority.

4.2 Phase II

4.2.1 Development of Manual on Postdisaster Response and Recovery

The Consultant shall produce the Manual in draft format and convene a workshop with relevant stakeholders to discuss all aspects of the Manual.

Upon receiving feedback, the Consultant will finalize the Manual and provide it in hard copy as well as in editable Microsoft Word and Adobe PDF formats.

4.2.2 Final Report

The Consultant shall prepare a Draft Final Report that includes all the results of the tasks and the draft of the Manual. The Draft Final Report shall be submitted to the Road Authority, with a subsequent workshop arranged by the Consultant to present the findings and recommendations to the Road Authority. The workshop shall take place within 10 working days after submission of the Draft Final Report, and the Road Authority will determine which (if any) of the stakeholders are to be invited to the workshop.

The Consultant shall revise and update the contents of the Draft Final Report by considering comments from the Road Authority. All the documents on the Manual shall also be finalized and included in the Final Report.

4.3 Workshop(s)

A copy of all workshop materials shall be provided in both Microsoft PowerPoint and Adobe PDF formats.

5 SCHEDULE

[All dates shall be reviewed by the Client to reflect the nature of geohazards on the network.]

This section sets forth the planned schedule of the tasks, their descriptions, and milestones such as the delivery times of reports. All tasks shall be completed within 180 days after contract effectivity according to the schedule described below.

- Submission of Draft Inception Report: within 10 days after contract effectivity. The Consultant shall prepare the IR including contents, methodologies, and a schedule of the tasks. Copies of the IR shall be delivered to the Road Authority. The Consultant shall meet with the Road Authority to discuss the Draft IR.
- Submission of Progress Report: within 90 days after contract effectivity. The Consultant shall prepare a Draft Progress Report that describes the contents mentioned in Sections 3.1.3 and 4.1.3. Copies of the Draft Progress Report shall be delivered to the Road Authority in electronic format plus one hard copy. The Consultant shall present and discuss the contents of the Draft Progress Report with the Road Authority. The Consultant shall prepare the Final Progress Report within 10 days of receiving feedback on the Draft Progress Report from the Road Authority.
- Submission of Draft Manual: within 60 days after submission of the Draft Progress Report. The Consultant shall prepare and submit the Draft Manual for review by the Road Authority and those stakeholders selected by the Road Authority. The Consultant shall present and discuss the contents of the Draft Manual with the Road Authority in a workshop-style setting including selected stakeholders. The Road Authority will be responsible for consolidating feedback on the Draft Manual.
- Submission of Draft Final Report: within 60 days after submission of the Draft Progress Report. The Consultant shall prepare a Draft Final Report comprising all of the results of the Work for review by the Road Authority and those stakeholders selected by the Road Authority. The Draft Manual is to be submitted as a stand-alone document, as noted earlier. The Draft Final Report shall be submitted to the Road Authority in electronic format plus one hard copy. The Consultant shall present and discuss the contents of the Draft Final Report with the Road Authority in a workshop-style setting including selected stakeholders. The Road Authority will be responsible for consolidating feedback on the Draft Final Report.
- Submission of Final Report: within 30 days after feedback on Draft Manual and Draft Final Report. The Consultant shall prepare the Final Report and Final Manual, revising the contents based on the comments from Road Authority. The Consultant shall submit all the deliverables including the Final Report to the Road Authority in both electronic format and five hard copies.

All reports shall be in the language(s) of English and <<enter a second language if required>>. In addition to the specified number of hard copies, electronic submissions shall be in the following formats:

- Draft reports need only be in PDF format, with permissions set to enable copying of contents and insertion of comments.
- Final reports are to be provided in both PDF format and in an editable format such as Microsoft Office (Word, Excel, and so on); ArcGIS; or other approved format.

6 PROFESSIONAL SKILLS AND EXPERIENCE REQUIRED

The Consultant's team will include qualified personnel with extensive experience in communications, geotechnical engineering, hydraulic engineering, risk assessment, civil engineering, and traffic modeling. The consulting firm shall have sufficient qualified personnel and resources, including international technical expertise and advisers, to provide all necessary professional, technical, and expert services required to accomplish all the services described above within the prescribed time.

The Consultant shall assemble a team for undertaking the scope of work and tasks described above. In responding to the ToR, consultancy organizations will provide curricula vitae, a description of roles and responsibilities, and a written statement of exclusivity and availability of key experts who will be working on the project.

Consulting firms may form joint ventures or associations with other consulting firms to enhance their capabilities, strengthen the technical responsiveness of their proposals, make available bigger pools of experts, and enhance the value and quality of their services. The following key personnel (whose experience and responsibilities are briefly described) will be considered in the evaluation of the technical proposals. Other expertise as required for the services to be rendered should be included as necessary and to reflect the consultant's responsiveness to the ToR.

It is estimated that this project will require 22 person-months from the team and will be completed within a period of 10 months. A list of suggested key personnel to be deployed by the Consultant, with appropriate minimum person-months of each as per Client's assessment, is shown in Table A.7.2. However, the Consultant can make their own assessment for the required composition and person-months for the key personnel and the phasing of their mobilization. The adequacy of the proposed composition will be assessed in the context of the proposal.

Table A.7.2 Estimated Input of Key Professional Staff

No.	Position	Person- months
1	Team leader or project manager	7
2	Communications specialist	6
3	Geotechnical specialist	1
4	Hydraulic engineer	1
5	Civil engineer	1
6	Traffic modeler	1
7	Road maintenance specialist	1
Total estimated key staff person-months		18

The person nominated as the team leader or project manager may also be nominated for any of the other roles.

The minimum qualifications and experience of key professional staff are summarized in Tables A.7.3–A.7.9. However, the Consultant may propose an effective team considered to be the most suitable for carrying out the project. The technical proposal must outline why the proposed composition of the team is considered capable and most suitable. In particular, many of the outputs require the use of GIS systems (ArcGIS), and the Consultant is to ensure that such skills exist within the team.

Table A.7.3 Qualifications and Skills of Team Leader or Project Manager

Qualifications and skills	Minimum of a master's degree in civil or highway engineering, computer science or information and communication technology (ICT), or a related topic, or equivalent professional experience of at least 15 years Fluency in English <<add other language as required>> language, both written and oral
General professional experience	At least 10 years of professional engineering experience
Specific professional experience	• Proven leadership and people management skills, including the ability to establish and maintain effective working relationships in an international multicultural working environment • Experience regarding work activities in transitioning or low- and middle-income countries • Experience in providing training or knowledge transfer to Client staff preferred • Minimum of 10 years' experience covering at least one aspect of the activities within this ToR (geotechnical, hydraulics, risk assessment, and so on)
Key responsibilities	• Provide overall management of all project activities • Coordinate and supervise the consultancy team and serve as the primary point of contact with the Client • Ensure high-quality deliverables • Lead the review and updating of the risk-based framework

Table A.7.4 Qualifications and Skills of Communications Specialist

Qualifications and skills	Minimum of a bachelor's degree in a relevant field and equivalent professional experience of at least 15 years Fluency in English language, both written and oral
General professional experience	At least five years of experience in communications related to transport projects
Specific professional experience	• Proven ability to take technical inputs from other team members and produce a high-quality communication document suitable for both technical and nontechnical reader • Experience regarding work activities in transitioning or low- and middle-income countries • Experience in writing communications documents for transport authorities (any mode) • Experience on at least one disaster awareness project in the past five years preferred
Key responsibilities	Overall lead for the development and writing of the Manual

Table A.7.5 Qualifications and Skills of Geotechnical Specialists

Qualification and skills	Minimum of a master's degree in civil, or road, or geotechnical engineering or a related topic, or equivalent professional experience of at least 10 years Fluency in English language, both written and oral
General professional experience	Expertise and experience in activities relating to life-cycle management of geotechnical assets
Specific professional experience	• At least 10 years of professional experience in areas relevant to this project • Understanding of landslide hazards and failure mechanisms of geotechnical assets • Understanding of risk-based evaluation methodologies preferred
Key responsibilities	Lead all geotechnical aspects of the assignment: develop land movement scenarios, estimate consequences, and so on

Table A.7.6 Qualifications and Skills of Hydraulic Specialist

Qualifications and skills	Minimum of a master's degree in civil, road, or geotechnical engineering or a related topic, or equivalent professional experience of at least 10 years Fluency in English language, both written and oral
General professional experience	Expertise and experience in activities relating to life-cycle management of geotechnical assets
Specific professional experience	• At least 10 years of professional experience in areas relevant to this project • Understanding of hydraulic modeling of catchments, climate modeling, and impact on road infrastructure • Understanding of risk-based evaluation methodologies preferred
Key responsibilities	Lead all geotechnical aspects of the assignment: develop hydraulic scenarios, estimate consequences, and so on

Table A.7.7 Qualifications and Skills of Civil Engineer

Qualifications and skills	Minimum of a master's degree in civil, road, or geotechnical engineering or a related topic, or equivalent professional experience of at least 10 years Fluency in English language, both written and oral
General professional experience	Expertise and experience in estimating the costs of highway works
Specific professional experience	• At least 10 years of professional experience in areas relevant to this project • Understanding of road damage caused by geohazards • Understanding of risk-based evaluation methodologies preferred
Key responsibilities	Develop cost estimates of damages to the road infrastructure for the scenarios under analysis

Table A.7.8 Qualifications and Skills of Traffic Modeler

Qualifications and skills	Minimum of a master's degree in civil, road, or geotechnical engineering or a related topic, or equivalent professional experience of at least 10 years Fluency in English language, both written and oral
General professional experience	Expertise in the development of network-level traffic models
Specific professional experience	• At least 10 years of professional experience in areas relevant to this project • Development of origin–destination (O–D) models, from data surveys techniques to model calibration and application • Detailed working knowledge of the traffic modeling platform proposed for use by the Consultant
Key responsibilities	Lead all aspects of the traffic modeling within this ToR

Table A.7.9 Qualifications and Skills of Road Maintenance Specialist

Qualifications and skills	At least 15 years' experience in road maintenance activities Tertiary qualification preferred Fluency in English language, both written and oral
General professional experience	Expertise in the undertaking of road maintenance activities and emergency response works
Specific professional experience	• At least 15 years of experience areas relevant to this project • At least 5 years managing a routine maintenance or emergency response depot • At least 5 years of undertaking nonspecialist asset condition inspections
Key responsibilities	Provide practical input to the development of the Manual

7 ANNEX A.7.1: LISTING OF RELEVANT INFORMATION

Attach information and data useful for the manual for postdisaster response and recovery such as location maps, lists of technical standards to be applied, etc. to be added.

ROAD GEOHAZARD RISK MANAGEMENT

APPENDIX B: OPERATIONS MANUAL 1 (OM1)

APPENDIX B

OPERATIONS MANUAL 1 (OM1)

ECONOMIC RISK ESTIMATION AND COST-BENEFIT ANALYSIS

1 INTRODUCTION

"Operations Manual 1: Economic Risk Estimation and Cost-Benefit Analysis" was developed to present the necessary procedures for projects related to (a) risk estimation of potential economic loss and (b) cost-benefit analysis of investments for road geohazard risk management.

The economic risk estimation and cost-benefit analysis are conducted for each geohazard-prone road location. A road location has different extents of road damage due to geohazards and different probabilities for the occurrence of a particular extent of road damage events. Typically a minor-extent event has a relatively high probability of occurrence, whereas a major-extent event has a relatively low probability.

For practical and simplified evaluation, this operations manual proposes that three extents of road damage be evaluated: (a) roadside (shoulder) damage only, (b) partial-width closing, and (c) whole-width closing. For road users, these three extents relate, respectively, to limited (if any) delays; additional delays without the need to reroute; and a need to reroute or cancel trips.

A risk index of "potential annual economic loss" is the result of the integral computations of the economic losses of several extents of road damage and their probabilities. This index is useful for understanding, from an economics perspective, the requirements of road geohazard risk management measures and the prioritization of studies for those measures among different hazard-prone road locations. And its biggest advantage as a risk index is that it can be used for the benefit estimation of investments for road geohazard risk management, which in turn is used in the cost-benefit analysis. The annual benefits of geohazard risk management (unit: currency per year) can be estimated as a difference between (a) the potential annual loss without measures implemented, and (b) the potential annual loss with measures in place.

The workflow of the geohazard risk (potential annual economic loss) estimation and cost-benefit analysis is shown in Table B.1 with the corresponding prototype spreadsheet tools. Because these prototype spreadsheet tools are formulated for universal and trial use, they should be modified in accordance with national conditions and feedback from the trial use.

Table B.1 Workflow of Geohazard Risk Estimation and Cost-Benefit Analysis of a Road Location

Operations manual section number (work item)	Evaluation output	Prototype spreadsheet tools
2.1 Evaluation of occurrence probabilities in years for different extents of road damage event	Occurrence probability in years (unit: years) for different extents of road damage events on a road location (*Note:* The occurrence probability in years is the inverse of the annual exceedance probability of occurrence [unit: % per year].)	Tool 1-1: Rating Checklist for Occurrence Probability in Years for Road Geohazard Events on a Road Location with Mountainside Slope Tool 1-2: Rating Checklist for Occurrence Probability in Years for Road Geohazard Events on a Road Location with Valley-Side Slope Tool 1-3: Rating Checklist for Occurrence Probability in Years for Road Geohazard Events on a Road Location with Crossing Stream Tool 1-4: Rating Checklist for Occurrence Probability in Years for Road Geohazard Events on a Bridge's Foundations
2.2 Economic loss estimation	Potential economic loss (unit: currency) for different extents of damage on a road location	Tool 2: Estimation of Potential Economic Loss caused by Geohazards on a Road Location
2.3 Estimation of risk and geohazard measures benefit	Potential annual economic loss (unit: currency per year) without measures on a road location Economic benefit as the expectation of annual average economic loss reduction (unit: currency per year)	Tool 3: Estimation of Potential Annual Economic Loss and Cost-Benefit Analysis for Geohazard on a Road Location Sheet 1: Estimation of Potential Annual Economic Loss and Benefit of Measures on a Road Location
2.4 Cost-benefit analysis	Net present value, cost-benefit ratio, and economic internal rate of return	Tool 3: Estimation of Potential Annual Economic Loss and Cost-Benefit Analysis for Geohazard on a Road Location Sheet 2: Cost-Benefit Analysis for Geohazard Measures on a Road Location

2 RISK ESTIMATION AND COST-BENEFIT ANALYSIS PROCEDURES

This section presents the procedures for risk (potential annual economic loss) estimation and cost-benefit analysis, by work item. Most of the procedures are explained along with the use of the prototype spreadsheet tools for each work item.

2.1 Evaluation of Occurrence Probabilities

Reference: Tool 1: Rating Checklists for Occurrence Probability in Years for Road Geohazard Events on a Road Location

The evaluation of occurrence probability is conducted by experts in engineering geology, hydrology, hydraulic engineering, and civil engineering with assistants trained in the evaluation procedures.

The occurrence probability in years for road damage events (without considering existing road geohazard measures) on a road location is rated for different road damage extents by summing up the scores of the occurrence probability in years. Different scores are assigned to each category of checklist items. The checklist items are road geohazard occurrence-related conditions of a road location, such as roadside slope inclination (with categories such as equal to or steeper than 45 degrees).

Finally, considering existing measures, the occurrence probabilities in years are adjusted considering (a) the design target occurrence probability in years of existing measures, and (b) the functioning or damaged condition of the existing measures.

2.1.1 Types of Evaluation Procedures

The occurrence probability measured in years is the inverse of the annual exceedance probability of occurrence. For geohazards with recurrent occurrence properties such as flow-type geohazards (earth or debris flow or flooding), the occurrence probability in years means the estimated time interval between damage events of similar extent on a road location. In such cases, another commonly used term for the occurrence probability in years is "return period."

On the other hand, fall, collapse, and slide-type geohazards (for example, rockfall, soil collapse, or debris mass sliding) do not have consistently recurrent occurrence properties. This is especially the case for slide-type geohazards; slopes become more stable after a slide because slopes become gentler by the sliding. For such geohazard types (with relatively inconsistent recurrent occurrence properties), the occurrence probability in years means the expected time period from the present to the next road damage event of a particular extent at a location.

Therefore, for consistency, this operations manual uses the same term for all types of geohazards: "occurrence probability in years."

The occurrence probability in years of several similar extents of road damage event at a road location (usually not more than three extent levels, such as roadside or shoulder damage only, or one-lane road closing) is determined by three accountability levels for the occurrence probability analysis: (a) basic method; (b) intermediate method; and (c) advanced method as further described below.

2.1.1.1 Basic Method: Low Cost, Low Accountability

- Determined using similar cases of historical road damage in the country or area for road locations under similar conditions, ranging from the average road age (starting from construction) to the average occurrence interval of damages on a road location either for roadside-only damage or for closure of one or more road lanes; or
- Determined using the approaching speed of the collapsing or sliding head edge of the cliff face at the road valley-side slope (periodical measurement using a tape measure, topographic survey data, or interpretation of different-date satellite images); or
- Determined by adopting the largest occurrence probability in years or return period (unit: years) of the rainfall frequency analysis[1] results from the nearest rainfall station data for rainfall amounts (in millimeters) of one day, two days, one hour, and two hours for a specific extent of historical road damage on an evaluated location.

2.1.1.2 Intermediate Method: Medium Cost, Medium Accountability

- Determined by using a rating checklist for the occurrence probability in years for road geohazard events on a road location (see sample prototype spreadsheet tools in this operations manual within the detailed description of procedures in Section 2.1.2, "Rating of Probability").

2.1.1.3 Advanced Method: High Cost, High Accountability

- For a slope (collapse or slide-type) geohazard, determined using a numerical model simulation with mathematical slope stability analysis: The outputs of the numerical model calculation are the simulated landform and the location of moved rocks and soils (after falling, collapsing, or sliding) by inputting different occurrence probabilities in years of rainfall or earthquake impact. The calculation is used to determine an assumed road damage extent: either the road width covered by soil or rock (for a road location with mountainside slope) or the width of the road body collapse (for a road location with valley-side slope); or
- For flow-type geohazards (for example, debris or earth flow or flooding), determined using hydrological analysis or numerical model simulation, as follows:
    - o A hydrological calculation can determine the peak flow rates (unit: meters per second) of flow-type geohazards such as debris or earth flow and flood (unit: cubic meters per second) for rainfall levels with different occurrence probabilities in years (or "return periods") for a stream crossing portion of a road.
    - o The occurrence probability in years of the road closing event due to a road submergence or debris or earth flow is determined by the comparison between (a) the flow capacity of the culverts or waterway under the bridge, and (b) the different peak flow rates of hydrological return periods at the stream crossing portion of the road.

[1] Rainfall frequency analysis requires more than 10 years of data for statistical significance. Each road location and geohazard type has different rainfall indexes such as rainfall amounts of one day, two days, one hour, and two hours to indicate an at-risk situation sharply. And it is a general practice that a rainfall data repository has only one-day rainfall amounts for the past 10 years, and some of them are one-hour rainfall amounts, but it is rare to have a repository of rainfall amounts at more precise time intervals. Therefore, this operations manual proposes to adopt the largest return period of frequency analysis results among the available rainfall amounts of one day, two days, one hour, and two hours.

2.1.2 Rating of Probability

The rating checklists refer to four location types:

- Tool 1-1: Road location with mountainside slope
- Tool 1-2: Road location with valley-side slope
- Tool 1-3: Road location with crossing stream
- Tool 1-4: Bridge foundations.

After selecting a rating tool, the tool user can rate the occurrence probability in years of a road location by (a) choosing either the most appropriate checklist-item category or all the applicable checklist-item categories; and (b) inputting the "effect on the occurrence probability in years of existing measures (unit: years)" if existing measures are in place. The rest of this subsection describes the procedure in detail.

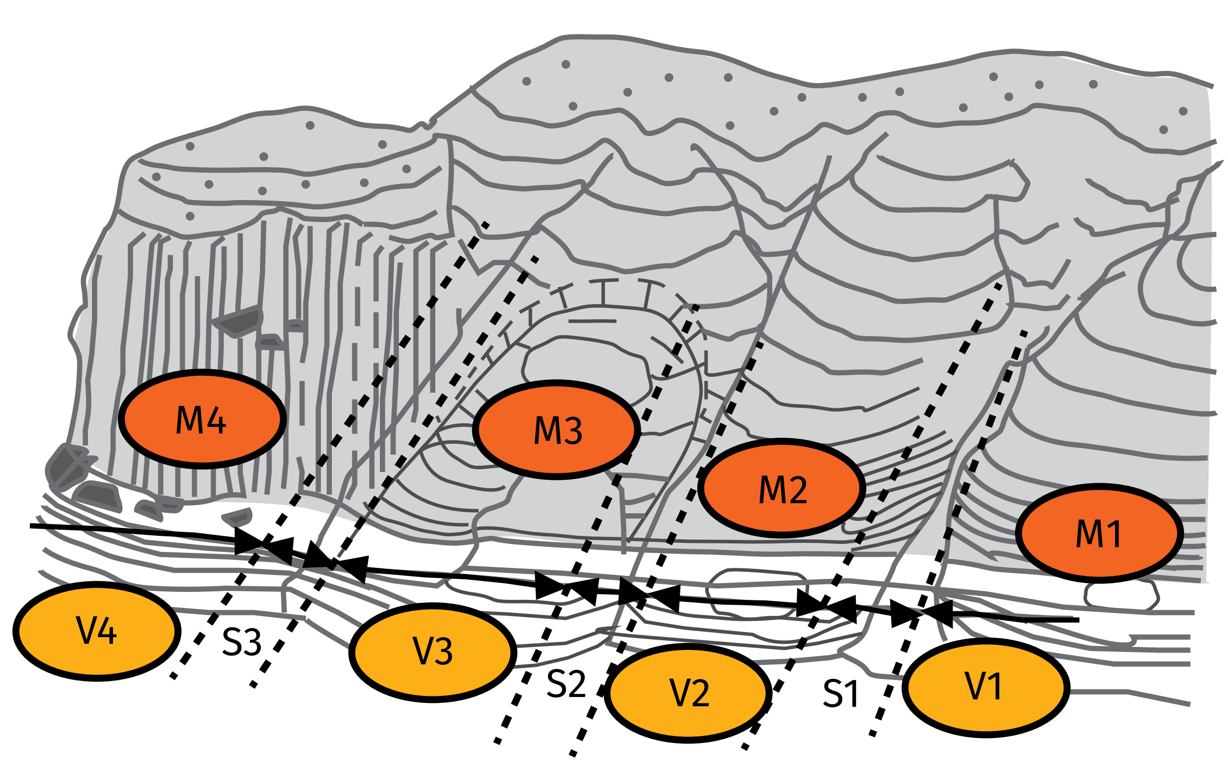
2.1.2.1 Selecting Rating Checklists

The rating checklists for the following four locational road geohazard damage types cover most of the cases found in the field—the tool being selected by users based on the locational conditions of the road (Figure B.1):

- Tool 1-1: Rating Checklist for Occurrence Probability in Years for Road Geohazard Events on a Road Location with Mountainside Slope (Figure B.2)
- Tool 1-2: Rating Checklist for Occurrence Probability in Years for Road Geohazard Events on a Road Location with Valley-Side Slope (Figure B.3)
- Tool 1-3: Rating Checklist for Occurrence Probability in Years for Road Geohazard Events on a Road Location with Crossing Stream (Figure B.4)
- Tool 1-4: Rating Checklist for Occurrence Probability in Years for Road Geohazard Events on a Bridge's Foundations (Figure B.5)

Tool 1-3 is for a flow capacity problem of a road-crossing waterway, and Tool 1-4 is for a hydraulic problem of a bridge's foundations. A crossing-stream road location with a bridge shall be analyzed using both Tool 1-3 and Tool 1-4.

Figure B.1 Road Locations for Geohazard Risk Evaluation, by Type



— — — —	Boundary of road location
——→	Extension along road of a road location
M	Road location with mountainside slope
V	Road location with valley-side slope
S	Road location with crossing stream

Source: Japan International Cooperation Agency (JICA), "The Study on Disaster Risk Management for Narayangharh-Mugling Highway: Final Report," JICA, Tokyo, 2009. ©JICA. Reproduced, with permission, from JICA; further permission required for reuse.

Note: M1, M2, M3, and M4 = road locations with mountainside slopes, using the Tool 1-1 spreadsheet. V1, V2, V3, and V4 = road locations with valley-side slopes, using the Tool 1-2 spreadsheet. S1, S2, and S3 = road locations with crossing streams, using the Tool 1-3 spreadsheet.

Figure B.2 *Tool 1-1:* *Rating Checklist for Occurrence Probability in Years for Road Geohazard Events on a Road Location with Mountainside Slope*

Too1 1-1: Rating Checklist for Occurrence Probability in Years for Road Geohazard Events on a Road Location with Mountainside Slope

[ ] White color cells are for users' input [ ] Gray colored cells include input names, instructions or calculation results

I. General Data	Location ID		Road Name		Station origin		Station destination		Extension along road (m)		Number of road lanes		Total road width (m)	0.00
Width of road from mountainside (m)	Mountainside roadside		1st lane		Center divider between 1st & 2nd lane		2nd lane		Center divider between 2nd & 3rd lane		3rd lane			
	Center divider between 3rd & 4th lane		4th lane		Center divider between 4th & 5th lane		5th lane		The other lanes and center dividers		Valley side roadside			

II. Observations:

III. Location Data, Geodesic Coordinates and Elevation of Road Center of Station of Origin Side	Latitude:		Longitude:		Elevation (m)	

IV. Historical road damage events due to geohazards (Three latest events)	Road damage magnitude (e.g. roadside only, one lane road closing, two lanes road closing, whole widths road closing)	Geohazard movement/material type	Date of event: Date	Month	Year	Historical occurrence frequency period in years of a specific magnitude of a road damage event (unit: years)	Description

V. Rating Checklist of Occurrence Probability in years without Existing Measures

Choose one for the most appropriate category

Check items and their categories for occurrence probability in years of a road damage event	Input '1' only for one applicable category	Score of occurrence probability in years: YpS of road damage event: roadside only	one lane closing	two lanes closing	Check items and their categories for occurrence probability in years of a road damage event	Input '1' only for one applicable category	Score of occurrence probability in years: YpS of road damage event: roadside only	one lane closing	two lanes closing
(1) Extension along road of hazardous road location: E					**(2) Slope inclination of mountainside slope up to inclination change point: SI**				
E ≥ 300 m		0.5	1.0	2.0	SI ≥ 45^O	1	0.5	1.0	2.0
300 m > E ≥ 200 m		1.0	2.0	4.0	45^O > SI ≥ 30^O		1.0	2.0	4.0
200 m > E ≥ 100 m	1	2.0	4.0	8.0	30^O > SI ≥ 15^O		2.0	4.0	8.0
100 m > E		3.0	6.0	8.0	15^O > SI		3.0	6.0	9.0
Score of occurrence probability in years for the selected category 1: SYp1		**2.0**	**4.0**	**8.0**	**Score of occurrence probability in years for the selected category 2: SYp2**		**0.5**	**1.0**	**2.0**
(3) Whole height of mountainside slope: WH					**(4) Height of mountainside slope up to inclination change point: H**				
WH ≥ 200 m		0.5	1.0	2.0	H ≥ 90 m	1	0.5	1.0	2.0
200 m > WH ≥ 100 m		1.0	2.0	4.0	90 m > H ≥ 60 m		1.0	2.0	4.0
100 m > WH ≥ 50 m	1	2.0	4.0	8.0	60 m > H ≥ 30 m		2.0	4.0	8.0
50 m > WH		3.0	6.0	9.0	30 m > H		3.0	6.0	9.0
Score of occurrence probability in years for the selected category 3: SYp3		**2.0**	**4.0**	**8.0**	**Score of occurrence probability in years for the selected category 4: SYp4**		**0.5**	**1.0**	**2.0**
(5) Distance from road mountainside slope toes to roadside :D					**(6) Shape of mountainside slope up to inclination change point**				
D ≥ 4 m		3.0	6.0	12.0	Valley type		0.5	1.0	2.0
4 m > D ≥ 2m		2.0	4.0	8.0	Straight type	1	1.0	2.0	4.0
2 m > D ≥ 1 m		1.0	2.0	4.0	Ridge type		2.0	4.0	8.0
1 m > D	1	0.5	1.0	2.0	Combined type		3.0	6.0	9.0
Score of occurrence probability in years for the selected category 5: SYp5		**0.5**	**1.0**	**2.0**	**Score of occurrence probability in years for the selected category 6: SYp6**		**1.0**	**2.0**	**4.0**
(7) Dominant materials of mountainside slope surface					**(8) Dominant geology of mountainside slope**				
Silt, clay	1	0.5	1.0	2.0	Quaternary: Sediment		1.0	2.0	4.0
Sand		0.8	1.6	3.2	Quaternary: Colluvium or Residual soil	1	2.0	4.0	8.0
Gravels		1.0	2.0	4.0	Quaternary: Sediment rock (week rock)		0.5	1.0	2.0
Cobbles, or Boulders		1.0	2.0	4.0	Quaternary: Volcanic deposit (pyroclastic)		0.5	1.0	2.0
Fractured rocks		2.0	4.0	8.0	Quaternary: Volcanic deposit (Breccia)		3.0	6.0	12.0
Weathered rock		2.0	4.0	8.0	Quaternary: Volcanic rock (Lava)		3.0	6.0	12.0
Soft intact rock		4.0	8.0	16.0	Neogene		3.0	6.0	12.0
Hard intact rock		10.0	20.0	30.0	Paleogene		2.0	4.0	8.0
Score of occurrence probability in years for the selected category 7: SYp7		**0.5**	**1.0**	**2.0**	Mesozoic		3.0	6.0	12.0
(9) Apparent inclination of dominant discontinuity against mountainside slope surface: AI					Paleozoic		4.0	8.0	16.0
AI ≥ 60^O		1.0	2.0	4.0	Precambrian		3.0	6.0	12.0
60^O > AI ≥ 20^O		0.5	1.0	2.0	**Score of occurrence probability in years for the selected category 8: SYp8**		**2.0**	**4.0**	**8.0**
20^O > AI ≥ 10^O		1.0	2.0	4.0	**(10) True angle of dominant discontinuity of rocky mountainside slope: D**				
10^O > AI ≥ 0^O		2.0	4.0	8.0	D ≥ 45^O		0.5	1.0	2.0
0^O > AI ≥ -10^O		3.0	6.0	9.0	45^O > D ≥ 15^O	1	1.0	2.0	4.0
-10^O > AI ≥ -20^O		4.0	8.0	16.0	15^O > D		2.0	4.0	8.0
-20^O > AI		5.0	10.0	20.0	Not existing		10.0	20.0	40.0
No discontinuity	1	6.0	12.0	24.0	Not rocky slope		10.0	20.0	40.0
Score of occurrence probability in years for the selected category 9: SYp9		**6.0**	**12.0**	**24.0**	**Score of occurrence probability in years for the selected category 10: SYp10**		**1.0**	**2.0**	**4.0**
(11) Spring (groundwater) condition of mountainside slope					**(12) Surface water of mountainside slope**				
Spring water is recognized all throughout the year		0.0	0.0	0.0	Surface water is recognized all throughout the year		0.5	1.0	2.0
Spring water is recognized seasonally	1	1.0	2.0	4.0	Surface water is recognized seasonally		1.0	2.0	4.0
Spring water is recognized abnormally		2.0	4.0	8.0	Surface water is recognized abnormally	1	2.0	4.0	8.0
Not seen		3.0	6.0	9.0	Not seen		3.0	6.0	9.0
Score of occurrence probability in years for the selected category 11: SYp11		**1.0**	**2.0**	**4.0**	**Score of occurrence probability in years for the selected category 12: SYp12**		**2.0**	**4.0**	**8.0**
(13) Dominant vegetation of mountainside slope					**(14) Type of mountainside slope up to inclination change point**				
Urban area		0.5	1.0	2.0	Natural slope	1	0.0	1.0	2.0
Deforested area	1	0.5	1.0	2.0	Engineered slope of cutting		1.0	2.0	4.0
Annual crops		0.5	1.0	2.0	Engineered slope of embankment		2.5	5.0	10.0
Moderate vegetation		2.0	4.0	8.0	Natural /engineered combined slope		0.5	1.0	2.0
Intense vegetation		4.0	8.0	16.0					
Score of occurrence probability in years for the selected category 13: SYp13		**0.5**	**1.0**	**2.0**	**Score of occurrence probability in years for the selected category 14: SYp14**		**0.0**	**1.0**	**2.0**
(15) Soil covering impervious bedrock at mountainside slope					**(16) The rock is hard on the upper part and soft at foot part of mountainside slope**				
Yes		0.0	0.0	0.0	Yes		0.0	0.0	0.0
No	1	6.0	12.0	18.0	No	1	6.0	12.0	18.0
Score of occurrence probability in years for the selected category 15: SYp15		**6.0**	**12.0**	**18.0**	**Score of occurrence probability in years for the selected category 16: SYp16**		**6.0**	**12.0**	**18.0**

Select all the applicable categories

Check items and their categories for occurrence probability in years of a road damage event	If applicable, Input '1'	Score of occurrence probability in years: YpS of road damage event: roadside only	one lane closing	two lanes closing	Check items and their categories for occurrence probability in years of a road damage event	If applicable, Input '1'	Score of occurrence probability in years: YpS of road damage event: roadside only	one lane closing	two lanes closing
(17) Abnormality (predictive phenomena to road damage)									
Minor collapse/fall on road mountainside slope	1	-5.0	-5.0	-5.0	Over 5 meters long continuous crack on the slope	1	-3.0	-3.0	-3.0
Fallen/inclined trees on road mountainside slope		-4.0	-4.0	-4.0	Apparent deformation by land-sliding	1	-20.0	-20.0	-20.0
Open cracks below an overhang on road mountainside slope		-4.0	-4.0	-4.0	Open cracks by toppling	1	-3.0	-3.0	-3.0
Cross open cracks to cause wedge shape slide on road mountainside slope		-4.0	-4.0	-4.0	Open cracks by sliding		-3.0	-3.0	-3.0
Continuous cracks (more than 5m) on road		-5.0	-5.0	-5.0	Depression on road	1	-5.0	-5.0	-5.0
Upheaval on road		-5.0	-5.0	-5.0	Surface erosion (1-10cm depth)		-1.0	-1.0	-1.0
Rill erosion (10- 100 cm depth) on road mountainside slope	1	-2.0	-2.0	-2.0	Slope subsurface erosion recognized on piping		-3.0	-3.0	-3.0
Erosion as trenches or gullies (deeper than 1 meter)		-5.0	-5.0	-5.0	**Result of adding up applicable categories' scores of occurrence probability in years 17: YpS17**		**-38.0**	**-38.0**	**-38.0**

Occurrence probability in years without considering existing measures: Yp_oEM of a road damage event; **If Σ(SYp1:SYp17) is • 1.1, Yp_oEM = Σ(YpS1:YpS 17)** **If Σ(YpS1:YpS17) is < 1.1 , Yp_oEM = 1.1**		
	for roadside damage only (years)	**1.1**
	for one lane road closing (years)	**26.0**
	for two lanes closing (years)	**73.0**

VI. Occurrence Probability in years considering Existing Measures

Existing measures, specify in the white cells to the right		**Input the effect on the occurrence probability in years of existing measures: EYp_EM (years):**	20.0

Occurrence Probability in years: Yp of a road damage event; **If Yp_oEM is • EYp_EM, Yp = EYp_EM** **If Yp_oEM is > EYp_EM, Yp = Yp_oEM**		
	for roadside damage only (years)	**20.0**
	for one lane road closing (years)	**26.0**
	for two lanes closing (years)	**73.0**

Note: Figures in red color are scores of the occurrence probability in years (YpSs) of each check item category, which are initially set and subject to be calibrated by statistical analysis using the database of this rating checklist. Each occurrence probability in years is calibrated using multivariate analysis minimizing the residual sum of squares between the actual years: Historical occurrence frequency period in years of the road damage events and the occurrence probability in years of the potential road damage events (calculation result of this rating tool).

Figure B.3 ***Tool 1-2:*** *Rating Checklist for Occurrence Probability in Years for Road Geohazard Events on a Road Location with Valley-Side Slope*

Tool 1-2: Rating Checklist for Probability in Years for Road Geohazard Events on a Road Location with Valley Side Slope

[ ] White color cells are for users' input [ ] Gray colored cells include input names, instruction letters or calculation results

I. General Data											
I. General Data	Location ID		Road Name		Station origin		Station destination		Extension along road (m)		Number of road lanes		Total road width (m)	0.00
Width of road from valley side (m)	Valley side Roadside		1st lane		Center divider between 1st & 2nd lane		2nd lane		Center divider between 2nd & 3rd lane		3rd lane	
	Center divider between 3rd & 4th lane		4th lane		Center divider between 4th & 5th lane		5th lane		The other lanes and center dividers		mountainside roadside	

II. Observations:

III. Location Data, Geodesic Coordinates and Elevation of Road Center of Station of Origin Side	Latitude:		Longitude:		Elevation (m)	

IV. Historical road damage events due to geohazards (Three latest events)	Road damage magnitude (e.g. roadside only, one lane road closing, two lane road closing, whole widths road closing)	Geohazard movement/material type	Date of event: Date	Month	Year	Historical occurrence frequency period in years of a specific magnitude of a road damage event (unit: years)	Description

V. Rating Checklist of Occurrence Probability in years without Existing Measures

Choose one for the most appropriate category

Check items and their categories for probability years of a road damage event	Input '1' only for one applicable category	Score of occurrence probability in years: YpS of road damage event: roadside only	one lane closing	two lanes closing	Check items and their categories for probability years: Yp of a road damage event	Input '1' only for one applicable category	Score of occurrence probability in years: YpS of road damage event: roadside only	one lane closing	two lanes closing
(1) Extension along road of hazardous road location: E					**(2) Slope inclination of valley side slope up to inclination change point: SI**				
E ≥ 300 m		0.4	0.8	1.2	SI ≥45^{O}	1	0.5	1.0	2.0
300 m > E ≥ 200 m		0.8	1.6	3.2	45^{O} > SI ≥ 30^{O}		1.0	2.0	4.0
200 m > E ≥ 100 m	1	2.0	4.0	8.0	30^{O} > SI ≥ 15^{O}		2.0	4.0	8.0
100 m > E		3.0	6.0	8.0	15^{O} > SI		3.0	6.0	9.0
Score of occurrence probability in years for the selected category 1: SYp1		**2.0**	**4.0**	**8.0**	**Score of occurrence probability in years for the selected category 2: SYp2**		**0.5**	**1.0**	**2.0**
(3) Whole height of valley side slope: WH					**(4) Height of valley side slope up to inclination change point: H**				
WH ≥ 90 m		0.5	1.0	2.0	H ≥ 90 m	1	0.5	1.0	2.0
90 m > WH ≥ 60 m		1.0	2.0	4.0	90 m > H ≥ 60 m		1.0	2.0	4.0
60 m > WH ≥ 30 m	1	2.0	4.0	8.0	60 m > H ≥ 30 m		2.0	4.0	8.0
30 m > WH		3.0	6.0	9.0	30 m > H		3.0	6.0	9.0
Score of occurrence probability in years for the selected category 3: SYp3		**2.0**	**4.0**	**8.0**	**Score of occurrence probability in years for the selected category 4: SYp4**		**0.5**	**1.0**	**2.0**
(5) Distance from road valley side edge to shoulder of valley side slope :D					**(6) Height from high water from valley side river to road surface: HW**				
D ≥ 2.0 m		3.0	6.0	12.0	HW • •2.0 m		0.5	1.0	2.0
2.0 m > D ≥ 1.0m		2.0	4.0	8.0	2.0 m > HW • •1.0 m	1	1.0	2.0	4.0
1.0 m > D ≥ 0.5 m		1.0	2.0	4.0	1.0 m > HW • •0.0 m		2.0	4.0	8.0
0.5 m > D	1	0.5	1.0	2.0	0.0 m > HW		3.0	6.0	9.0
Score of occurrence probability in years for the selected category 5: SYp5		**0.5**	**1.0**	**2.0**	**Score of occurrence probability in years for the selected category 6: SYp6**		**1.0**	**2.0**	**4.0**
(7) Shape of valley side slope up to inclination change point					**(8) Rain water flow road to valley side slope**				
Valley type		0.5	1.0	2.0	Yes and no drainage facility in valley side slope	1	0.00	0.00	0.00
Straight type	1	1.0	2.0	4.0	Yes and in the unlined drainage facilities		2.00	4.00	6.00
Ridge type		2.0	4.0	8.0	Yes and in the lined drainage facilities				
Combined type		3.0	6.0	9.0	No				
Score of occurrence probability in years for the selected category 7: SYp7		**1.0**	**2.0**	**4.0**	**Score of occurrence probability in years for the selected category 8: SYp8**		**0**	**0**	**0**
(9) Dominant materials of valley slope surface					**(10) Dominant geology of valley side slope**				
Silt, clay	1	0.5	1.0	2.0	Quaternary: Sediment		1.0	2.0	4.0
Sand		0.8	1.6	3.2	Quaternary: Colluvium or Residual soil	1	2.0	4.0	8.0
Gravels		1.0	2.0	4.0	Quaternary: Sediment rock (week rock)		0.5	1.0	2.0
Cobbles, or Boulders		1.0	2.0	4.0	Quaternary: Volcanic deposit (pyroclastic)		0.5	1.0	2.0
Fractured rocks		2.0	4.0	8.0	Quaternary: Vocalic deposit (Breccia)		3.0	6.0	12.0
Weathered rock		2.0	4.0	8.0	Quaternary: Volcanic rock (Lava)		3.0	6.0	12.0
Soft intact rock		4.0	8.0	16.0	Neogene		3.0	6.0	12.0
Hard intact rock		10.0	20.0	30.0	Paleogene		2.0	4.0	8.0
Score of occurrence probability in years for the selected category 9: SYp9		**0.5**	**1.0**	**2.0**	Mesozoic		3.0	6.0	12.0
(11) Apparent inclination of dominant discontinuity against valley side slope surface: AI					Paleozoic		4.0	8.0	16.0
AI ≥60^{O}		1.0	2.0	4.0	Precambrian		3.0	6.0	12.0
60^{O} > AI ≥ 20^{O}		0.5	1.0	2.0	**Score of occurrence probability in years for the selected category 10: SYp10**		**2.0**	**4.0**	**8.0**
20^{O} > AI ≥ 10^{O}		1.0	2.0	4.0	**(12) True angle of dominant discontinuity of rocky valley side slope: D**				
10^{O} > AI ≥ 0^{O}		2.0	4.0	8.0	D ≥45^{O}		0.5	1.0	2.0
0^{O} > AI ≥ -10^{O}		3.0	6.0	9.0	45^{O} > D ≥ 15^{O}	1	1.0	2.0	4.0
-10^{O} > AI ≥ -20^{O}		4.0	8.0	16.0	15^{O} > D		2.0	4.0	8.0
-20^{O} > AI		5.0	10.0	20.0	Not existing		10.0	20.0	40.0
No discontinuity	1	6.0	12.0	24.0	Not rocky slope		10.0	20.0	40.0
Score of occurrence probability in years for the selected category 11: SYp11		**6.0**	**12.0**	**24.0**	**Score of occurrence probability in years for the selected category 12: SYp12**		**1.0**	**2.0**	**4.0**
(13) Spring (groundwater) condition of valley side slope					**(14) Surface water of valley side slope**				
Spring water is recognized all throughout the year		0.0	0.0	0.0	Surface water is recognized all throughout the year		0.5	1.0	2.0
Spring water is recognized seasonally	1	1.0	2.0	4.0	Surface water is recognized seasonally		1.0	2.0	4.0
Spring water is recognized abnormally		2.0	4.0	8.0	Surface water is recognized abnormally	1	2.0	4.0	8.0
Not seen		3.0	6.0	9.0	Not seen		3.0	6.0	9.0
Score of occurrence probability in years for the selected category 13: SYp13		**1.0**	**2.0**	**4.0**	**Score of occurrence probability in years for the selected category 14: SYp14**		**2.0**	**4.0**	**8.0**
(15) Dominant vegetation of valley side slope					**(16) Type of valley side slope up to inclination change point**				
Urban area		0.5	1.0	2.0	Natural slope	1	0.0	1.0	2.0
Deforested area	1	0.5	1.0	2.0	Engineered slope of cutting		1.0	2.0	4.0
Annual crops		0.5	1.0	2.0	Engineered slope of embankment		2.5	5.0	10.0
Moderate vegetation		2.0	4.0	8.0	Natural /engineered combined slope		0.5	1.0	2.0
Intense vegetation		4.0	8.0	16.0					
Score of occurrence probability in years for the selected category 15: SYp15		**0.5**	**1.0**	**2.0**	**Score of occurrence probability in years for the selected category 16: SYp16**		**0.0**	**1.0**	**2.0**
(17) Soil covering impervious bedrock at valley side slope					**(18) The rock is hard on the upper part and soft at head part of valley side slope**				
Yes		0.0	0.0	0.0	Yes		0.0	0.0	0.0
No	1	6.0	12.0	18.0	No	1	6.0	12.0	18.0
Score of occurrence probability in years for the selected category 17: SYp17		**6.0**	**12.0**	**18.0**	**Score of occurrence probability in years for the selected category 18: SYp18**		**6.0**	**12.0**	**18.0**

Select all the applicable categories

Check items and their categories for probability years: Yp of a road damage event	If applicable, Input '1'	Score of probability years: YpS of road damage event: roadside only	one lane closing	two lanes closing	Check items and their categories for probability years: Yp of a road damage event	If applicable, Input '1'	Score of probability years: YpS of road damage event: roadside only	one lane closing	two lanes closing
(19) Abnormality (predictive phenomena to road damage)									
Minor collapse/fall on road valley side slope	1	-5.0	-5.0	-5.0	Over 5 meters long continuous crack on the slope	1	-3.0	-3.0	-3.0
Fallen/inclined trees on road valley side slope		-4.0	-4.0	-4.0	Apparent deformation by land-sliding	1	-20.0	-20.0	-20.0
Open cracks below an overhang on road valley side slope		-4.0	-4.0	-4.0	Open cracks by toppling	1	-3.0	-3.0	-3.0
Cross open cracks to cause wedge shape slide on road valley side slope		-4.0	-4.0	-4.0	Open cracks by sliding		-3.0	-3.0	-3.0
Continuous cracks (more than 5m) on road		-5.0	-5.0	-5.0	Depression on road	1	-5.0	-5.0	-5.0
Upheaval on road		-5.0	-5.0	-5.0	Surface erosion (1-10cm depth)		-1.0	-1.0	-1.0
Rill erosion (10- 100 cm depth) on road valley side slope	1	-2.0	-2.0	-2.0	Slope subsurface erosion recognized on piping		-3.0	-3.0	-3.0
Erosion as trenches or gullies (deeper than 1 meter)		-5.0	-5.0	-5.0	**Result of adding up applicable categories' scores of occurrence probability in years 19: YpS19**		**-38.0**	**-38.0**	**-38.0**

Occurrence probability in years without considering existing measures: Yp_oEM of a road damage event;		
If Σ(SYp1:SYp19) is • 1.1, Yp_oEM = Σ(YpS1:YpS19)	**for roadside damage only (years)**	**1.1**
If Σ(YpS1:YpS19) is < 1.1 , Yp_oEM = 1.1	**for one lane road closing (years)**	**28.0**
	for two lanes closing (years)	**82.0**

Existing measures, specify in the white cells to the right		**Input the effect on the occurrence probability in years of existing measures: EYp_EM (years):**	20.0

Occurrence Probability in years: Yp of a road damage event;		
If Yp_oEM is • EYp_EM, Yp = EYp_EM	**for roadside damage only (years)**	**20.0**
If Yp_oEM is > EYp_EM, Yp = Yp_oEM	**for one lane road closing (years)**	**28.0**
	for two lanes closing (years)	**82.0**

Note: Figures in red color are scores of the occurrence probability in years (YpSs) of each check item category, which are initially set and subject to be calibrated by statistical analysis using the database of this rating checklist. Each occurrence probability in years is calibrated using multivariate analysis minimizing the residual sum of squares between the actual years: Historical occurrence frequency period in years of the road damage events and the occurrence probability in years of the potential road damage events (calculation result of this rating tool).

Figure B.4 *Tool 1-3: Rating Checklist for Occurrence Probability in Years for Road Geohazard Events on a Road Location with Crossing Stream*

Too1 1-3: Rating Checklist for Occurrence Probability in Years for Road Geohazard Events on a Road Location with Crossing Stream

[ ] White color cells are for users' input [ ] Gray colored cells include input names, instructions or calculation results

I. General Da	Location ID		Road Name		Station origin		Station destination		Extension along road (m)		Number of road lanes		Total road width (m) 0.00
Width of road from upstream side (m)	Upstream side roadside		1st lane		Center divider between 1st & 2nd lane		2nd lane		Center divider between 2nd & 3rd lane		3rd lane		
	Center divider between 3rd & 4th lane		4th lane		Center divider between 4th & 5th lane		5th lane		The other lanes and center dividers		Downstream side roadside		

II. Observations:

III. Location Data Geodesic Coordinates and Elevation of Road Center of Station of Origin Side	Latitude:		Longitude:		Elevation (m)

IV. Historical road damage events due to geohazards (Three latest events)	Road damage magnitude (e.g. roadside only, one lane road closing, two lane road closing, whole widths road closing)	Geohazard movement/ material type	Date of event: Date	Month	Year	Historical occurrence frequency period in years of a specific magnitude of a road damage event (unit: years)	Description

V. Rating Checklist of Occurrence Probability in years without Existing Measures

Choose one for the most appropriate category

Check items and their categories for occurrence probability in years of a road damage event	Input '1' only for one applicable category	Score of occurrence probability in years: YpS of road damage event: roadside only	one lane closing	two lanes closing	Check items and their categories for occurrence probability in years of a road damage event	Input '1' only for one applicable category	Score of occurrence probability in years: YpS of road damage event: roadside only	one lane closing	two lanes closing
(1) Width of stream at the infrastructure crossing point: W					**(2) Gradient of stream bed at the infrastructure crossing: G**				
W • •10 m		3.0	6.0	12.0	G • 20^{O}	1	0.0	0.0	0.0
10 m > W • •5 m		2.0	4.0	8.0	20^{O} > G • •15^{O}		1.0	2.0	4.0
5 m > W • •3 m	1	1.0	2.0	4.0	15^{O} > G • •10^{O}		2.0	4.0	8.0
3 m > W		0.0	0.0	0.0	10^{O} > G		3.0	4.0	12.0
Score of occurrence probability in years for the selected category 1: SYp1		**1.0**	**2.0**	**4.0**	**Score of occurrence probability in years for the selected category 2: SYp2**		**0.0**	**0.0**	**0.0**
(3) Area of drainage basin of the stream at the infrastructure crossing point: A					**(4) Height from stream bottom to infrastructure at the crossing stream point: H**				
A • •1.0 km2	1	3.0	4.0	12.0	H • •5 m		3.0	4.0	12.0
1.0 km^2 > A • •0.2 km^2		2.0	4.0	8.0	5 m > H • •2 m		2.0	4.0	8.0
0.2 km^2 > A • •0.1 km^2		1.0	2.0	4.0	2 m > H • •1 m		1.0	2.0	4.0
0.1 km^2 > A		0.0	0.0	0.0	1 m > H	1	0.0	0.0	0.0
Score of occurrence probability in years for the selected category 3: SYp3		**3.0**	**4.0**	**12.0**	**Score of occurrence probability in years for the selected category 4: SYp4**		**0.0**	**0.0**	**0.0**
(5) Dominant materials of valley slope surface					**(6) Dominant geology of valley side slope**				
Silt, clay	1	3.0	6.0	12.0	Quaternary: Sediment		1.0	2.0	4.0
Sand		2.0	4.0	8.0	Quaternary: Colluvium or Residual soil	1	2.0	4.0	8.0
Gravels		1.0	2.0	4.0	Quaternary: Sediment rock (week rock)		0.5	1.0	2.0
Cobbles, or Boulders		0.0	0.0	0.0	Quaternary: Volcanic deposit (pyroclastic)		0.5	1.0	2.0
Fractured rocks		10.0	20.0	40.0	Quaternary: Volcanic deposit (Breccia)		3.0	6.0	12.0
Weathered rock		10.0	20.0	40.0	Quaternary: Volcanic rock (Lava)		3.0	6.0	12.0
Soft fresh rock		15.0	30.0	60.0	Neogene		3.0	6.0	12.0
Hard fresh rock		20.0	40.0	80.0	Paleogene		2.0	4.0	8.0
Score of occurrence probability in years for the selected category 5: SYp5		**3.0**	**6.0**	**12.0**	Mesozoic		3.0	6.0	12.0
(7) Dominant vegetation of valley side slope					Paleozoic		4.0	8.0	16.0
Urban area		0.5	1.0	2.0	Precambrian		3.0	6.0	12.0
Deforested area	1	0.5	1.0	2.0	**Score of occurrence probability in years for the selected category 6: SYp6**		**2.0**	**4.0**	**8.0**
Annual crops		0.5	1.0	2.0	**(8) Stream water at crossing point of the road**				
Moderate vegetation		2.0	4.0	8.0	Stream water is recognized all throughout the year		0.5	1.0	2.0
Intense vegetation		4.0	8.0	16.0	Stream water is recognized seasonally	1	1.0	2.0	4.0
Score of occurrence probability in years for the selected category 7: SYp7		**0.5**	**1.0**	**2.0**	Surface water is recognized abnormally		2.0	4.0	8.0
(9) Difference of stream gradient (DEG) of crossing point, in comparison of around 30 m length of upstream and down stream areas					Not seen		10.0	20.0	40.0
					Score of occurrence probability in years for the selected category 8: SYp8		**1.0**	**2.0**	**4.0**
Upstream is steeper than downstream: DEG < 10^{O}		2.0	5.0	10.0	**(10) Plan shape of stream at the crossing point of infrastructure**				
Upstream is steeper than downstream: 10^{O} ≤ DEG	1	5.0	10.0	20.0	Straight	1	2.0	4.0	8.0
Down stream is steeper than upstream: DEG < 10^{O}		2.0	5.0	10.0	Curved		0.0	0.0	0.0
Down stream is steeper than upstream: 10^{O} ≤ DEG		3.0	7.0	15.0	**Score of occurrence probability in years for the selected category 10: SYp10**		**2.0**	**4.0**	**8.0**
Score of occurrence probability in years for the selected category 9: SYp9		**5.0**	**10.0**	**20.0**					
(11) Slope failure situation in the drainage area of the stream									
Newly-formed collapses (bare/no vegetation) are existing in main valley and branch valleys	1	0.0	0.0	0.0	Newly-formed collapses (bare/no vegetation) are existing only in main valley		1.0	2.0	4.0
Newly-formed collapses (bare/no vegetation) are existing only in branch valleys		2.0	4.0	8.0	Newly-formed collapses (bare/no vegetation) are not recognized		3.0	6.0	12.0
					Score of occurrence probability in years for the selected category 11: YpS11		**0.0**	**0.0**	**0.0**

Select all the applicable categories

Checking items/categories for return period of a disaster event	If applicable, Input '1'	Score of probability years: YpS of road damage event: roadside only	one lane closing	two lanes closing	Checking items/categories for return period of a disaster event	If applicable, Input '1'	Score of probability years: YpS of road damage event: roadside only	one lane closing	two lanes closing
(11) Abnormality (predictive phenomena to road damage)									
Past debris flow deposit/trace is recognized on the infrastructure	1	-5.0	-10.0	-20.0	Drift wood is recognized in the stream	1	-3.0	-3.0	-3.0
Past damage is recognized on the infrastructure		-4.0	-4.0	-4.0	**Result of adding up applicable categories' scores of occurrence probability in years 12: YpS12**		**-8.0**	**-13.0**	**-23.0**

Probability years without existing measures: Yp_oEM of a road damage event; **If Σ(YpS1:YpS12) is • 1.1 Yp_oEM = Σ(YpS1:YpS 12)** **If Σ(YpS1:YpS12) is < 1.1 Yp_oEM = 1.1**	**for roadside damage only (years)**	**13.5**
	for one lane road closing (years)	**29.0**
	for two lanes closing (years)	**66.0**
Existing structural measures, specify in the white cells to the right	**Input the effect on the occurrence probability in years of existing measures: EYp_EM (years):**	20.0
Occurrence probability in years: Yp of a road damage event; **If Yp_oEM is • EYp_EM, Yp = EYp_EM** **If Yp_oEM is > EYp_EM, Yp = Yp_oEM**	**for roadside damage only (years)**	**20.0**
	for one lane road closing (years)	**29.0**
	for two lanes closing (years)	**66.0**

Note: Figures in red color are scores of the occurrence probability in years (YpSs) of each check item category, which are initially set and subject to be calibrated by statistical analysis using the database of this rating checklist. Each occurrence probability in years is calibrated using multivariate analysis minimizing the residual sum of squares between the actual years: Historical occurrence frequency period in years of the road damage events and the occurrence probability in years of the potential road damage events (calculation result of this rating tool).

Figure B.5 ***Tool 1-4:*** *Rating Checklist for Occurrence Probability in Years for Road Geohazard Events on a Bridge's Foundations*

Tool 1-4: Rating Checklist for Occurrence Probability in Years for Road Geohazard Events on a Bridge's Foundations

[ ] White color cells are for users' input — [gray] Gray colored cells include input names, instructions or calculation results

I. General Data	Location ID		Road Name		Station origin		Station destination		Bridge Extension (m)		Number of road lanes	4	Total bridge width (m)	
			Number of bridge spans											

II. Observations

III. Location Data Geodesic Coordinates and Elevation of Road Center of Station of Origin Side	Latitude:		Longitude:		Elevation (m)	

IV. Historical road damage events due to geohazards (Three latest events)	Road damage magnitude (e.g. roadside only, one lane road closing, two lane road closing, whole widths road closing)	Geohazard movement/material type	Date of event: Date	Month	Year	Historical occurrence frequency period in years of a specific magnitude of a road damage event (unit: years)	Description

V. Rating Checklist of Occurrence Probability in years without Existing Measures

Choose one for the most appropriate category

Check items and their categories for occurrence probability in years of a road damage event	Input '1' only for one applicable category	Score of occurrence probability in years: YpS of complete bridge closing due to road geohazard damage event	Check items and their categories for occurrence probability in years of a road damage event	Input '1' only for one applicable category	Score of occurrence probability in years: YpS of complete bridge closing due to road geohazard damage event
(1) General geomorphology			**(2) Historical change of river course**		
Alluvial plane		3.0	Outside of the bridge length	1	0.0
Alluvial fan		1.0	Inside of the bridge length		0.5
Valley plane	1	0.0	Not applicable		1.0
Mountain area		0.0			
Score of occurrence probability in years for the selected category 1: SYp1		**0.0**	**Score of occurrence probability in years for the selected category 2: SYp2**		**0.0**
(3) Narrow portion in river course			**(4) Bridge length shorter than river width**		
by nature	1	0.5	Applicable		0.0
by artificial structures		0.0	Not applicable		5.0
not applicable		5.0			
Score of occurrence probability in years for the selected category 3: SYp3		**0.5**	**Score of occurrence probability in years for the selected category 4: SYp4**		**0.0**
(5) Position of bridge foundation (abutments and piers) in river (When there is more than one bridge foundation, select the far low side of the applicable category)			**(6) Crossing Angle (CA) of bridge foundation (abutment and piers) against flow direction**		
Under low water level in curved river course	1	0.0	.CA ≥20º		0.0
Under low water level in straight river course		2.0	20 º > CA ≥15º	1	1.0
Under high water label in curved river course		5.0	15 º > CA ≥10º		1.5
Under high water level in straight river course		7.0	10º > CA ≥ 5º		8.0
Outside high water level		15.0	5º > CA		10.0
Score of occurrence probability in years for the selected category 5: SYp5		**0.0**	**Score of occurrence probability in years for the selected category 6: SYp6**		**0.0**
(7) Type of substructure			**(8) Depth Ratio (DR: Depth of embedment/ width or diameter of foundation)**		
Caisson foundation	1	10.0	Unknown or DR < 0.1		0.0
Pile foundation		20.0	0.1 ≤ DR < 0.5		1.0
Spread foundation		5.0	0.5 ≤ DR < 1.0		2.0
Unknown		0.0	1.0 ≤ DR < 1.5		5.0
			1.5 ≤ DR		10.0
Score of occurrence probability in years for the selected category 7: SYp7		**10.0**	**Score of occurrence probability in years for the selected category 8: SYp8**		**0.0**
(9) River foundation protection against scouring			**(10) Dominant river materials**		
No existing and falling head is more than 1 meter		0.0	Silt/Clay		0.5
No existing and falling head is less than 1 meter	1	0.5	Sand	1	1.5
Not full width protection works		1.0	Gravel		2.0
Full width protection works at upstream portion only		4.0	Cobble		3.0
Full width protection works at down stream portion only		5.0	Boulder		3.5
Full width protection works at both of upstream and downstream area		5.5	Bedrock		6.0
Score of occurrence probability in years for the selected category 9: SYp9		**0.5**	**Score of occurrence probability in years for the selected category 10: SYp10**		**1.5**
(11) Existence of driftwood or garbage					
Recognized		0.0	Not recognized	1	3.0
Sparsely recognized		1.5	**Score of occurrence probability in years for the selected category 11: SYp11**		**3.0**
(12) Right side river bank (heading downstream) protection by revetment			**(13) Left side river bank (heading downstream) protection by revetment**		
Revetment, serious deformation		0.5	Revetment, serious deformation		0.5
Revetment, minor deformation	1	5.0	Revetment, minor deformation	1	5.0
Revetment, no deformation		14.0	Revetment, no deformation		14.0
No revetment, serious erosion		0.0	No revetment, serious erosion		0.0
No revetment, no serious erosion		1.0	No revetment, no serious erosion		1.0
Score of occurrence probability in years for the selected category 12: SYp12		**5.0**	**Score of occurrence probability in years for the selected category 13: SYp13**		**5.0**
(14) Riverbed degradation			**(15) Riverbed aggradation**		
In Full Width		0.0	In Full Width		0.0
Partial Width	1	0.2	Partial Width	1	0.2
Not applicable		4.0	Not applicable		5.0
Score of occurrence probability in years for the selected category 14: SYp14		**0.2**	**Score of occurrence probability in years for the selected category 15: SYp15**		**0.2**
(16) Difference of riverbed slope gradient (DEG) at bridge, in comparison to around 100 m length of upstream and downstream areas			**(17) Height (H) of falling head at the bridge**		
Down stream is steeper than upstream — DEG < 10	1	1.0	H < 1 m		8.0
Down stream is steeper than upstream — 10 ≤ DEG		0.0	1 m < H ≤ 2m	1	4.0
Upstream is steeper than downstream — DEG < 10		0.0	2m < H		2.0
Upstream is steeper than downstream — 10 ≤ DEG		16.0	5m < H		0.0
Score of occurrence probability in years for the selected category 16: SYp16		**1.0**	**Score of occurrence probability in years for the selected category 17: SYp17**		**4.0**
(18) Damage of falling works					
Equal to more than 50% of width, or no falling works		0.0	No damage of falling works		8.0
Less than 50% of Width		8.0	**Score of occurrence probability in years for the selected category 18: SYp18**		**0.0**
(19) Damage (such as open cracks, scouring) on substructure (for collapsed bridges, before disaster situation)			**(20) Damage (such as open cracks) on superstructure (for collapsed bridges, before disaster situation)**		
Applicable		0.0	Applicable		0.0
Applicable, but only to some extent		2.0	Applicable, but only to some extent		1.0
Not applicable		3.0	Not applicable		2.0
Unknown		0.0	Unknown		0.0
Score of occurrence probability in years for the selected category 19: SYp19		**0.0**	**Score of occurrence probability in years for the selected category 20: SYp20**		**0.0**

Occurrence probability in years without considering existing measures: Yp_oEM of a road damage event; **If Σ(YpS1:YpS20) is ≥ 1.1 Yp_oEM = Σ(YpS1:YpS 20)** **If Σ(YpS1:YpS20) is < 1.1 Yp_oEM = 1.1**	**for complete bridge closing (years)**	**32.4**
Existing structural measures, specify in the white cells to the right	**Input the effect on the occurrence probability in years of existing measures: EYp_EM (years):**	50.0
Occurrence probability in years: Yp of a road damage event; **If Yp_oEM is • EYp_EM Yp = EYp_EM** **If Yp_oEM is > EYp_EM Yp = Yp_oEM**		**50.0**

Note: Figures in red color are scores of the occurrence probability in years (YpSs) of each check item category, which are initially set and subject to be calibrated by statistical analysis using the database of this rating checklist. Each occurrence probability in years is calibrated using multivariate analysis minimizing the residual sum of squares between the actual years: Historical occurrence frequency period in years of the road damage events and the occurrence probability in years of the potential road damage events (calculation result of this rating tool).

2.1.2.2 Use of Rating Checklists

All of the tools follow the same structure: the tool user enters values into white cells only; the gray cells show either the entered names, instructions, or calculation results. Each of the Tool 1 checklists includes the following data fields:

I. General data: Users input items—including locational identification, road name, and station (origin and destination)—using numbers and letters.

II. Observations: Observations are written using text freely, including information such as the assumed geohazard type (types of material and movement) and any remarkable abnormalities of the road location.

III. Location data: Users input location data—including the geodesic coordinates and the elevation of the road center station on the origin side—using numbers and letters.

IV. Historical road damage events due to geohazards (three latest events): Users here enter the data for the road geohazard damage database formulation, which is used to calibrate the rating checklist for the occurrence probability in years. Historical records of road damage are collected from (a) the records of road management authorities or offices; (b) historical media accounts (such as newspapers or online resources); or (c) recordings of interviews with stakeholders (for example, road management authority staff, routine road users, residents, or business personnel along the road). If damage data from more than three road geohazard events are available, the data are recorded on a separate spreadsheet file. If the items entered are not clearly specified, they should not be entered but instead only noted in the description column.

- ***Road damage extent:*** Select road damage extent from the most appropriate category: “roadside only”; “one-lane road closing”; “two-lane road closing”; “specific-lanes road closing (for example, three-lane road closing), if any”; or “whole-width road closing.” Use the worst situation of damage (in terms of closure width) from the road location.
- ***Geohazard movement/material type:*** Select dominant material or with second-most dominant material from bedrock, debris, earth, and water.
- ***Date of event:*** Enter the day, month, and year of a road damage event. If the hour of the event can also be specified, note it in the description column.
- ***Historical occurrence frequency period in years of a specific extent of a road damage event (unit: years):*** This is the inverse value of the actual annual exceedance frequency (unit: percentage per year) of a specific extent of historical damage event. The historical occurrence frequency period is evaluated as the recurrence interval of damage events due to geohazards at a location that are of similar extent. Calculate it using the most appropriate of the following methods:
    - ***If data are available for several historical damage events of similar extent:*** historical occurrence frequency period in years of a specific extent of a road damage event (unit: years) = (number of years of record + 1) ÷ (number of road damage events of similar extent at a location).
    - ***If data are available for only one specific extent of historical damage event, and if it is under heavy rain:*** historical occurrence frequency period in years of a historical damage event of a specific extent (unit: years) = largest return period of the frequency analysis results among the rainfall amounts in millimeters for one day, two days, one hour, and two hours from the nearest rainfall station.2

- o ***If data are available for only one specific extent of damage event, and if it is under normal weather conditions:*** historical occurrence frequency period in years of a specific extent of a road damage event (unit: years) = age (number of years between road construction and the road damage event) + 1.

- ***Description:*** Enter any remarkable information about the historical damage in the description column.

V. Rating checklist of occurrence probability in years: There are 17, 19, 11, and 20 checklist items, respectively, for rating the occurrence probability in years of a road damage event for a road location with mountainside slope (Tool 1-1); for a road location with valley-side slope (Tool 1-2); for a road location with crossing stream (Tool 1-3); and for a bridge's foundations (Tool 1-4). The requirement is to input only "1" within the white cells to the right of the category description. The procedure for most checklist items is to choose the most appropriate category; however, for the "Abnormality (predictive phenomena to road damage)" checklist item (in Tools 1-1, 1-2, and 1-3), the procedure is to select all the applicable categories. The calculation result of the tool sheets is the occurrence probability in years without considering existing measures (unit: years).

VI. Occurrence probability in years considering existing measures:[3] This section (Section VI in Tool 1-1 or the bottom of Section V in Tools 1-2, 1-3, and 1-4) includes a description of the existing measures and "the effect on the occurrence probability in years of existing measures." In the white cell for "existing measures," describe the details of any existing road geohazard risk management measures and their condition (functioning or damaged). Next, "the effect on the occurrence probability in years of existing measures" can be determined using one of the following procedures:

- ***If measures are nonexistent or not functioning:*** If no measures exist or if the existing measures are seriously damaged and apparently not functioning, input a "0" in the white cell for "the effect of existing measures on the occurrence probability in years."

- ***For fall-, collapse-, or slide-type geohazards:*** Road slope stabilization measures and protection measures against geohazards are designed as permanent measures. Structural measures are designed to achieve adequate safety factors of slope stability (that is, resistance force against slope failure).4 The design safety factors of slope stability and "the effect on the occurrence probability in years" are experimentally proposed for these tools (Table B.2) as in the following equation:

  EOP = 500 x (DSF-1),

  *where **EOP** is the effect on the occurrence probability in years on a road location (unit: years), and*

  ***DSF** is the design safety factor of slope stability.*

  Slope drainage and vegetation (bioengineering) also affect the slope stability experimentally, but they cannot be considered in the safety factors for slope stability. These tools propose that "the effect on the occurrence probability in years" be set to "0" because the effect is reflected in the checklist items for "abnormality (predictive phenomena to road damage)" in the rating checklist of occurrence probability in years.[5]

  Road protection structures against fall- or collapse-type geohazards (such as rockfall or soil collapse) are designed with bigger protection capacity against the assumed maximum impact forces or energy that may affect them, considering a safety factor. The "effect on the occurrence probability in years" for these structures is set to 100 years, taking into account the occurrence of unexpected impact force or energy events.

Table B.2 Proposed Values for the Effect of Slope Stability Measures on the Occurrence Probability in Years for Road Geohazard Events

Effect on the occurrence probability in years on a road location (years)	Design safety factor of slope stability (resistance force against slope failure force)
100	1.20
75	1.15
60	1.12
50	1.10

Note: "Slope failure" covers slope fall, collapse, or slide.

- ***For river erosion and flow-type (hydrological) geohazards:*** The measures for river erosion and flow-type geohazards such as flood or earth or debris flow are planned and designed using hydrological or hydraulic analysis. The concept of "return period" (unit: years) is used, which is interchangeable with the "occurrence probability in years" (unit: years) in hydrological and hydraulic analysis. The "effect on the occurrence probability in years" can be set equal to the design return period of the flow-type geohazard. The "effect on the occurrence probability in years" of existing measures of the landscape ecosystem conservation works (for example, riverbed erosion protection and reforestation of landscape ecosystem) is thus entered as "0" because the measures' effect is reflected in the rating tools' checklist items for "abnormality (predictive phenomena to road damage)."

2 Rainfall station information including station name, recording organization, and distance to the evaluated road location are entered in the description column. Rainfall frequency analysis requires more than 10 years of data for statistical significance. Each road location and geohazard type has different rainfall indexes (such as rainfall amount of one day, two days, one hour, and two hours) to indicate an at-risk situation sharply. And rainfall stations generally keep on record only one-day rainfall amounts for the past 10 years. Some of them keep on record one-hour rainfall amount data, but this more-precise record keeping is rare. Therefore, this operations manual proposes the adoption of the largest return period of the frequency analysis results among the available rainfall amount data of one day, two days, one hour, and two hours.

3 In Tool 1-1, the field for data on "existing structural measures" is in section "VI." In Tools 1-2, 1-3, and 1-4, the fields for data on "existing structural measures" are shown at the bottom of section "V."

4 Note that "slope failure" is a term used to cover slope fall, collapse, or slide.

5 The "abnormality (predictive phenomena to road damage)" checklist item is number (17) in Tool 1-1; number (19) in Tool 1-2; and number (11) in Tool 1-3. No such checklist item exists in Tool 1-4 because that tool applies only to flow-type geohazard or hydrological hazards on a bridge's foundations—not to fall-, collapse-, or slide-type geohazards.

2.1.2.3 Calculation Structure of the Rating Checklists

The following text describes the rating checklists' general function; provides examples of checklist items and categories; summarizes the differences in occurrence probability evaluation procedures for varying extents of road damage events; summarizes the two-step procedure for calculating occurrence probability; and finally details each step of that procedure.

General function of the rating checklists. The rating checklists calculate the occurrence probability in years of road damage (unit: years) automatically by selecting different categories of checklist items that contribute to increasing or decreasing geohazard damage risk on a road location. This occurrence probability without considering existing measures is calculated by adding up the scores of occurrence probability in years that are assigned to each category of checklist items. Finally, the occurrence probabilities considering existing measures are adjusted considering (a) the design targets of the road geohazard measures, and (b) the condition (functioning or damaged) of those measures.

Examples of checklist items and categories. One of the checklist items for a road location with mountainside slope (Tool 1-1) is "dominant materials of mountainside slope surface," and the category choices include silt or clay, sand, gravels, cobbles or boulders, fractured rocks, and so on. Other checklist items include slope inclination, distance from slope toes to roadside, and "abnormality (predictive phenomena to road damage)."

Evaluation of occurrence probability in years for road damage events of different extents. The probability of road geohazard damage to more than three road lanes is very low and requires large-magnitude induced causes such as extremely intense rainfall or earthquakes. Because these rating tools are formulated on the premise of a calibration by multivariate statistical analysis using historical road damage events, the "occurrence probability in years" ratings for a damage extent of more than a three-lane road closing are statistically insignificant; thus, they are not treated in the rating checklists for a road location with mountainside slope (Tool 1-1), valley-side slope (Tool 1-2), or crossing stream (Tool 1-3).

The occurrence probability in years for varying road damage extents is evaluated using other procedures (described earlier in Section 2.1.1, "Types of Evaluation Procedures")—namely, (a) to adopt the return period for an extreme historical rainfall of similar extent that induced a road closing exceeding three lanes at a similar road location; or (b) to use numerical geohazard simulation analysis. Alternatively, an arithmetic extrapolation using "occurrence probability in years" rating results for one-lane and two-lane road closings can be used.

Only the "whole-width closing" road damage extent is applied for road damage events due to hydrological geohazards on a bridge (Tool 1-4) because the bridge damage due to geohazards is commonly a whole-width road closing.

Two-step procedure for rating occurrence probability in years of road damage events. The rating is conducted in two steps: (1) calculation of the occurrence probability in years without considering existing measures, and (2) adjusted calculation of the occurrence probability in years considering existing measures (Figure B.6).

Figure B.6 Rating Procedure of Occurrence Probability in Years of Road Geohazard Events on a Road Location

Step 1: Calculation of occurrence probability in years without considering existing measures

Input: "1" in white cells next to category description by either choosing the most appropriate category of checklist items or selecting all the applicable categories of checklist items

↓

Occurrence probability in years without considering existing measures = sum of the "occurrence probability in years" scores assigned to each category selected for all checklist items (if smaller than 1.1 years, it is adjusted to 1.1 years)

↓

Step 2: Calculation of occurrence probability in years considering existing measures

Input: effect on the occurrence probability in years of existing measures (unit: years)

↓

Occurrence probability in years on a road damage location = the larger of either the "effect on the occurrence probability in years of existing measures" or "occurrence probability in years without considering existing measures"

Step 1: Rating of occurrence probability in years without considering existing measures. After the user enters "1" into a checked cell (white cell) next to a given category's description—choosing either the most appropriate checklist-item category or all of the applicable categories—the gray cells automatically display the scores for "occurrence probability in years without considering existing measures." To rate this occurrence probability, the tool simply adds up the scores assigned to the checklist-item categories that match the situation of the road location. (If the calculation result is smaller than 1.1 years, it is adjusted to 1.1 years.)

In the rating tools for road locations with mountainside slope (Tool 1-1), valley-side slope (Tool 1-2), and crossing stream (Tool 1-3), three damage extents ("roadside damage only," "one lane closing," and "two lanes closing") are rated. In the rating tool for hydrological geohazard on a bridge (Tool 1-4), this occurrence probability is rated only for one extent (whole-width road closing).

Each category is assigned an occurrence probability in years score (unit: years) based on its level of contribution to the generation of road geohazard damage. A category that contributes to risk reduction is assigned a large score; a category that contributes to a risk increase is assigned a small or negative score.

Each of the scores assigned to different checklist-item categories is calibrated through multivariate statistical analysis, using the checklist-item or category results of the rating checklists as well as data of historical road geohazard damage events (a specific extent and their evaluated "historical occurrence frequency period in years"), which were also entered into the rating checklist. (The "historical occurrence frequency period in years" input was described earlier in Section 2.1.2.2, "Use of Rating Checklists," within "IV. Historical road damage events due to geohazards.")

The calibration by multivariate regression analysis is conducted to search for the most suitable scores of occurrence probability in years to assign to each category of checklist items by minimizing the residual sum of the squares of "occurrence probability in years" (rating results of the tools) and "historical occurrence frequency period in years." The calibration is conducted for three extent levels: roadside damage only, one lane closing, and two lanes closing. The data entered for the statistical analysis are (a) the road damage events of available historical road damage locations, and (b) the selected categories' results from the rating checklists as applicable in a nation or region.

The following formula illustrates this multivariate regression analysis (Equation [B.1] and Figure B.7):

(B.1) **Yp_oEM= Σ YpS**,

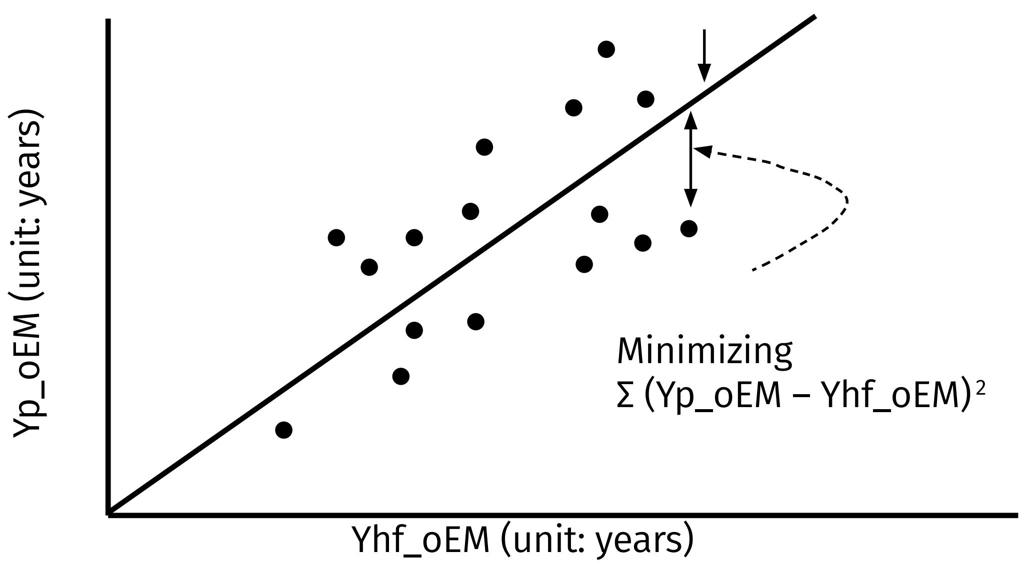
where **Yp_oEM** = occurrence probability in years of road damage event without considering existing measures for a road location (unit: years);

YpS = score of occurrence probability in years assigned to each category of checklist items in the rating tool (unit: years); and

Yhf_oEM = historical occurrence frequency period in years (unit: years).

Note that the calibration is conducted only for data of locations without existing measures in place. In this case, slope vegetation; cutting or removal of unstable rock or soil; earthworks; and landscape ecosystem management facilities (groundsill slope stabilization works upstream in a landscape ecosystem, or reforestation) are not included as existing measures because they are reflected in other checklist items in the rating tool.

Figure B.7 Multivariate Regression Analysis to Assign the Most Suitable Scores of Occurrence Probability in Years to Each Checklist–Item Category



Note: Scatterplot dots indicate road locations. Yp_oEM = occurrence probability in years of road damage event (without considering existing measures). Yhf_oEM = historical occurrence frequency in years.

Step 2: Calculation of occurrence probability in years considering existing measures. Once the rating tool users input the "effect on the occurrence probability in years of existing measures (unit: years)" into the designated cell, the "occurrence probability in years of existing measures" is calculated. (The "effect on the occurrence probability in years of existing measures [unit: years]" was described earlier in Section 2.1.2.2, "Use of Rating Checklists," within "VI. Occurrence probability in years considering existing measures.") The "occurrence probability in years on a road damage location (considering existing measures)" is the bigger of these two values: "effect on the occurrence probability in years of existing measures" or "occurrence probability in years without considering existing measures."

2.2 Economic Loss Estimation

Reference: Tool 2: Estimation of Potential Economic Loss Caused by Geohazards on a Road Location

"Tool 2: Estimation of Potential Economic Loss caused by Geohazards on a Road Location" (Figure B.8 and Figure B.9) is formulated to be used by anyone with access to the required data.

The economic loss estimation requires the assumption of rates or coefficients, which are provided in this section provisionally. To conduct an accurate potential economic loss estimate, research and analysis of the rates or coefficients to meet the prevailing conditions of the corresponding nation or region are required.

The tool is prepared so that the tool users input values into the white cells only. The gray cells include either entered names, instructions, or calculation results.

Figure B.8 ***Tool 2:*** *Estimation of Potential Economic Loss Caused by Geohazards on a Road Location (Traffic Economics Data Portion)*

Too1 2: Estimation of Potential Economic Loss Caused by Geohazards on a Road Location

white color cells are for users' input | gray colored cells include instructions or results calculated by this tool

Location ID		Road Name	
Station Origin		Station Destination	
Extension along road (m)		Number of road lanes	
Estimated condition of road damage extent		Occurrence probability in years of the road damage event : Yp (years)	
	Specify closing lanes/ total lanes		

Traffic Economics Data Input

No.	Item		Unit	Symbol or calculated formula	Quantity
(1)	**Probable extension of road damage of the road location**	of roadside-only	m	PERD_si	
		of partial width-closing	m	PERD_pw	
		of whole-width closing	m	PERD_ww	
			m	**PERD**	**0**
(2)	**Distance of evaluated road sections measured along the evaluated road sections between the origin/destination intersections with detour roads**		**km**	**Ders**	
(3)	**Distance of detour road sections measured along the detour road sections between the origin/destination intersections with evaluated roads**		**km**	**Ddrs**	
(4)	Annual average daily traffic in the evaluated road location	Vehicle type 1	vehicles/day	AADTerl_t1	
		Vehicle type 2	vehicles/day	AADTerl_t2	
		Vehicle type 3	vehicles/day	AADTerl_t3	
		Vehicle type 4	vehicles/day	AADTerl_t4	
		Vehicle type 5	vehicles/day	AADTerl_t5	
		Vehicle type 6	vehicles/day	AADTerl_t6	
		Vehicle type 7	vehicles/day	AADTerl_t7	
	Annual average daily traffic at evaluated road location		**vehicles/day**	**AADTerl**	**0**
(5)	Vehicle operation cost on evaluated road sections	Vehicle type 1	currency/km/vehicle	VOCers_t1	
		Vehicle type 2	currency/km/vehicle	VOCers_t2	
		Vehicle type 3	currency/km/vehicle	VOCers_t3	
		Vehicle type 4	currency/km/vehicle	VOCers_t4	
		Vehicle type 5	currency/km/vehicle	VOCers_t5	
		Vehicle type 6	currency/km/vehicle	VOCers_t6	
		Vehicle type 7	currency/km/vehicle	VOCers_t7	
	Average vehicle operation cost on evaluated road sections		**currency/km/vehicle**	**AVOCers**	**#VALUE!**
(6)	Vehicle operation cost of detour road sections	Vehicle type 1	currency/km/vehicle	VOCdrs_t1	
		Vehicle type 2	currency/km/vehicle	VOCars_t2	
		Vehicle type 3	currency/km/vehicle	VOCdrs_t3	
		Vehicle type 4	currency/km/vehicle	VOCdrs_t4	
		Vehicle type 5	currency/km/vehicle	VOCdrs_t5	
		Vehicle type 6	currency/km/vehicle	VOCdrs_t6	
		Vehicle type 7	currency/km/vehicle	VOCdrs_t7	
	Average vehicle operation cost of detour road sections		**currency/km/vehicle**	**AVOCdrs**	**#VALUE!**
(7)	Vehicle speed in the evaluated road sections	Vehicle type 1	km/hour	VSers_t1	
		Vehicle type 2	km/hour	VSers_t2	
		Vehicle type 3	km/hour	VSers_t3	
		Vehicle type 4	km/hour	VSers_t4	
		Vehicle type 5	km/hour	VSers_t5	
		Vehicle type 6	km/hour	VSers_t6	
		Vehicle type 7	km/hour	VSers_t7	
	Average vehicle speed of evaluated road section		**km/hour**	**AVSers**	**#VALUE!**
(8)	Vehicle speed in the evaluated road location	Vehicle type 1	km/hour	VSehrl_t1	
		Vehicle type 2	km/hour	VSehrl_t2	
		Vehicle type 3	km/hour	VSehrl_t3	
		Vehicle type 4	km/hour	VSehrl_t4	
		Vehicle type 5	km/hour	VSehrl_t5	
		Vehicle type 6	km/hour	VSehrl_t6	
		Vehicle type 7	km/hour	VSehrl_t7	
	Average vehicle speed at the evaluated road location		**km/hour**	**AVSerl**	**#VALUE!**
(9)	Vehicle speed in the detour road section	Vehicle type 1	km/hour	VSdrs_t1	
		Vehicle type 2	km/hour	VSdrs_t2	
		Vehicle type 3	km/hour	VSdrs_t3	
		Vehicle type 4	km/hour	VSdrs_t4	
		Vehicle type 5	km/hour	VSdrs_t5	
		Vehicle type 6	km/hour	VSdrs_t6	
		Vehicle type 7	km/hour	VSdrs_t7	
	Average vehicle speed in detour road section		**km/hour**	**AVSdrs**	**#VALUE!**
(10)	Value of vehicle travel time savings in the evaluated road location	Vehicle type 1	currency/vehicle/hour	VTTSerl_t1	
		Vehicle type 2	currency/vehicle/hour	VTTSerl_t2	
		Vehicle type 3	currency/vehicle/hour	VTTSerl_t3	
		Vehicle type 4	currency/vehicle/hour	VTTSerl_t4	
		Vehicle type 5	currency/vehicle/hour	VTTSerl_t5	
		Vehicle type 6	currency/vehicle/hour	VTTSerl_t6	
		Vehicle type 7	currency/vehicle/hour	VTTSerl_t7	
	Average value of vehicle travel time savings in the evaluated road location		**currency/vehicle/hour**	**AVTTSerl**	**#VALUE!**
(11)	Average number of passengers of vehicles	Vehicle type 1	person/vehicle	ANP_t1	
		Vehicle type 2	person/vehicle	ANP_t2	
		Vehicle type 3	person/vehicle	ANP_t3	
		Vehicle type 4	person/vehicle	ANP_t4	
		Vehicle type 5	person/vehicle	ANP_t5	
		Vehicle type 6	person/vehicle	ANP_t6	
		Vehicle type 7	person/vehicle	ANP_t7	
	Average number of passengers of vehicles at the evaluated road location		**person/vehicle**	**ANPVerl**	**#VALUE!**
(12)	Average number of operators of vehicles	Vehicle type 1	person/vehicle	ANO_t1	
		Vehicle type 2	person/vehicle	ANO_t2	
		Vehicle type 3	person/vehicle	ANO_t3	
		Vehicle type 4	person/vehicle	ANO_t4	
		Vehicle type 5	person/vehicle	ANO_t5	
		Vehicle type 6	person/vehicle	ANO_t6	
		Vehicle type 7	person/vehicle	ANO_t7	
	Average number of operators of vehicles at the evaluated road location		**person/vehicle**	**ANOerl**	**#VALUE!**
(13)	**Average number of passengers plus operators of vehicles at the evaluated road location**		**person/vehicle**	**ANP&Oerl**	**#VALUE!**
(14)	Average price of a new vehicles	Vehicle type 1	currency/vehicle	APNV_t1	
		Vehicle type 2	currency/vehicle	APNV_t2	
		Vehicle type 3	currency/vehicle	APNV_t3	
		Vehicle type 4	currency/vehicle	APNV_t4	
		Vehicle type 5	currency/vehicle	APNV_t5	
		Vehicle type 6	currency/vehicle	APNV_t6	
		Vehicle type 7	currency/vehicle	APNV_t7	
	Average price of a new vehicle at the evaluated road location		**currency/vehicle**	**APNVerl**	**#VALUE!**
(15)	Average use years of running vehicle at the evaluated road location		years	**AUYRVerl**	
	Annual value reduction percentage for vehicles		percentage	**AVRPV**	
	Average value of a running vehicle at the evaluated road location		**currency/vehicle**	**AVRVerl = APNVerl x (1-AVRPV)^{AUYRVerl}**	**#VALUE!**

Figure B.9 ***Tool 2:*** *Estimation of Potential Economic Loss Caused by Geohazards on a Road Location (Economic Loss Data Portion)*

Economic Loss	(1)	**Road infrastructure recovery cost**	**currency**	**RIRC**		
	(2)	Estimated number of days for road recovery from damages of the roadside only	days	ENDR_si		
		Estimated number of days for road recovery from damages of closure of the partial road width	days	ENDR_pw		
		Estimated number of days for road recovery from damages of closure of the whole road width	days	ENDR_ww		
		Percentage of vehicle speed reduced due to the roadside damage only	percentage	PVSR_si		
		Percentage of vehicle speed reduced due to the partial- width road closing damage	percentage	PVSR_pw		
		Estimated number of vehicles affected by the roadside-only damage	vehicles	ENVA_si =	AADTerl x ENDR_si	0
		Estimated number of vehicles affected by the closure of the partial road-width due to road damage	vehicles	ENVA_pw =	AADTerl x ENDR_pw	0
		Estimated number of vehicles affected by the closure of the whole road-width due to road damage	vehicles	ENVA_ww =	AADTerl x ENDR_ww	0
		Average increase in vehicle travel time due to road damage in the evaluated road location by the roadside only damage	hours/ vehicle	AIVTT_si =	PERD_si/1000/(AVSerl x (1- PVSR_si))	#VALUE!
		Average increase in vehicle travel time due to road damage in the evaluated road location by the partial-width road closing damage	hours/ vehicle	AIVTT_pw =	PERD_pw/1000/(AVSerl x (1- PVSR_pw))	#VALUE!
		Road disturbance traffic loss due to roadside only damage	currency	RDTL_si =	ENVA_si x AIVTT_si x AVTTSerl	#VALUE!
		Road disturbance traffic loss due to partial width road closing	currency	RDTL_pw =	ENVA_pw x AIVTT_pw x AVTTSerl	#VALUE!
		Average waiting time of vehicles due to the closure of the whole road -width	hours/ vehicle	AWT_ww =	ENDR_ww x 24/2	0
		Waiting loss due to whole width road closing	currency	WL_ww =	ENVA_ww x AWT_ww x AVTTSerl	#VALUE!
		Average increase in vehicle operating cost due to detour due to closure of the whole road width	currency/ vehicle	AIVOCd_ww =	AVOCdrs x Ddrs - AVOCers x Ders	#VALUE!
		Average increase in travel time due to detour of vehicles due to the closure of the whole road width	hours/vehicle	AITTd_ww =	Ddrs/AVSdrs -Ders/AVSers	#VALUE!
		Average loss due to increase in travel time for detour of vehicles due to closure of the whole-width	currency/ vehicle	ALITT_ww =	AITTd_ww x AVTTSerl	#VALUE!
		Average loss incurred due to detour of vehicles due to the closure of the whole road width	currency/ vehicle	ALd_ww =	AIVOCd_ww +ALITT_ww	#VALUE!
		Detour loss due to closure of the whole road width	currency	DL_ww =	ENVA_ww x ALd_ww	#VALUE!
		Road interruption traffic loss due to the closure of whole road width	currency	RITL_ww =	lesser value between WL_ww and DL_ww	#VALUE!
		Road Interruption/ Disturbance Traffic Loss	**currency**	**RIDTL =**	**RDTL_si + RDTL_pw+ RITL_ww**	**#VALUE!**
	(3)	Unit value of human lives lost	currency/person	UVHLL		
		Number of humans affected momentarily by a road damage event due to geohazard	person	NHAMRDEG =	PERD/(AVSerl x 1000) x (AADTerl/24) x ANP&Oerl	#VALUE!
		Percentage of human lives lost to number of human affected by road damage event due to geohazard	percentage	PHLL		
		Human Lives Lost	**currency**	**HLL = UVHLL x NHAMRDEG x PHLL**		**#VALUE!**
	(4)	Number of vehicles affected momentarily by road damage event due to geohazard	vehicles	NVAMRDEG =	PERD/(AVSerl x 1000) x (AADTeri/24)	#VALUE!
		Percentage of vehicle lost to number of vehicle affected by road damage event due to geohazard	percentage	PVL		
		Vehicles Loss	**currency**	**VL= AVRVerl x NVAMRDEG x PVL**		**#VALUE!**
	(5)	**Other Loss**	**currency**			
Total Loss			**currency**	**TL = RIRC+RIDTL+HLL+VL**		**#VALUE!**

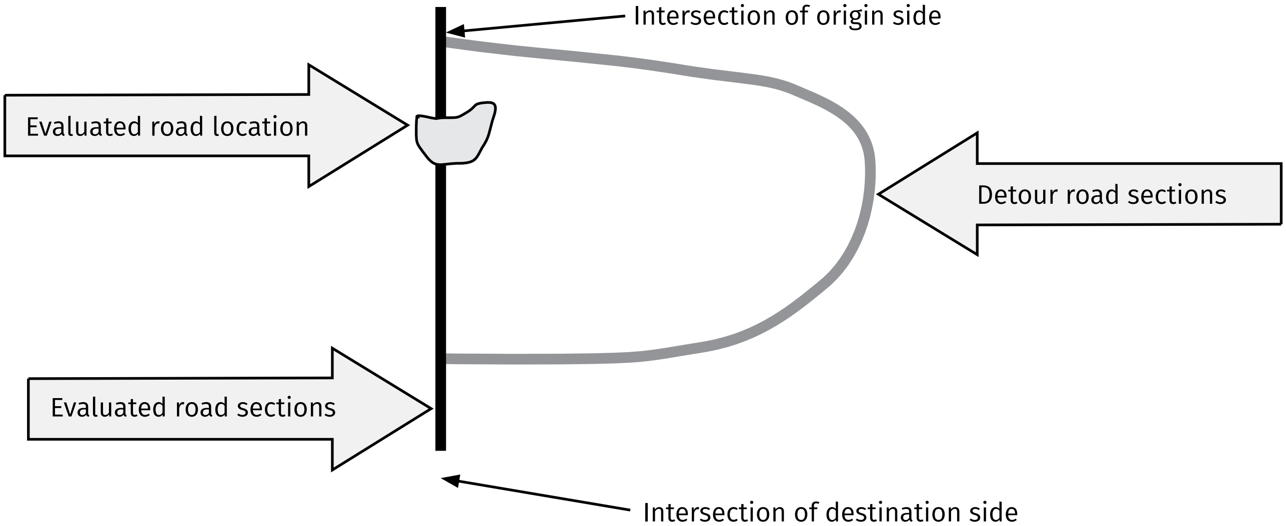
2.2.1 Data Input for Traffic Economics

Different traffic economic values related to the evaluated road locations and road sections, as well as the detour road sections to be considered, should be entered by users in the tool as follows:

(1) Probable extension of road damage on the road location (unit: meters): The "probable extension of road damage" is entered in meters using three levels of disaster extent: roadside-only damage, partial-width closing, and whole-width closing (damage affecting the total width of all traffic lanes). The probable extension is determined by experts in engineering geology, hydrology, or hydraulic engineering.

(2) Distance of evaluated road sections (unit: kilometers): The distance or length of the evaluated road sections is measured along the road sections themselves, between the origin and destination intersections with the detour roads that can help users to find an alternative route when the evaluated location is closed to traffic completely. The detour road sections shall have at least the same or higher traffic capacity than the evaluated road sections (Figure B.10).

Figure B.10: Instructions for Measuring Evaluated and Detour Road Sections



(3) Distance of detour road sections (unit: kilometers): The distance of detour road sections is measured along the detour road sections between their origin and destination intersections with the evaluated road sections. The detour road shall have at least the same or higher traffic capacity than the evaluated road sections.

(4) Annual average daily traffic of evaluated road location (unit: vehicles per day): The annual average daily traffic (AADT) is the annual average daily volume of vehicles at a given point on a road section. The total daily traffic figure may vary depending on day of the week, public holidays, seasonal trends, and climate conditions. The AADT is the average figure for the year. A tool user inputs the AADT of each vehicle type on an evaluated road location using the data of the nearest available traffic survey point along the road section. This tool calculates the AADT of the evaluated road location as the total of the abovementioned AADTs of vehicle types.

(5) Average vehicle operation cost on evaluated road sections (unit: currency per kilometer per vehicle): Vehicle operation cost (VOC) refers to costs that vary with vehicle use, including fuel, tires, maintenance, repairs, and mileage-dependent depreciation costs. VOC is calculated for different road sections, taking into consideration the road conditions and vehicle type. A tool user calculates the VOC on the evaluated road sections for each vehicle type weighted by the proportion of distance for each of the road conditions (which have different VOCs) along the evaluated road sections and inputs them in this tool. This tool calculates the average VOC on the evaluated road sections. It is determined from the VOC of each vehicle type on the evaluated road sections weighted by the proportion of AADTs of each vehicle type at the evaluated road location.

(6) Average vehicle operation cost of detour road sections (unit: currency per kilometer per vehicle): A tool user calculates the VOC on the detour road sections for each vehicle type weighted by the proportion of distance for each of the road conditions (which have different VOCs) along the detour road sections and inputs them in this tool. This tool calculates the average VOC on the detour road sections. It is determined from the VOC of each vehicle type on the detour road sections weighted by the proportion of AADTs of each vehicle type at the evaluated road location.

(7) ***Average vehicle speed of evaluated road section (unit: kilometers per hour):*** A tool user calculates the vehicle speed on the evaluated road sections for each vehicle type and weights them by the proportion of distance for each of the road conditions (which have different vehicle speeds) along the evaluated road sections and inputs them in this tool. This tool calculates the average vehicle speed on the evaluated road sections. It is determined from the vehicle speed of each vehicle type on the evaluated road sections weighted by the proportion of AADTs of each vehicle type at the evaluated road location.

(8) ***Average vehicle speed at the evaluated road location (unit: kilometers per hour):*** A tool user inputs the vehicle speed in the evaluated road location determined by the road condition at the location for each vehicle type. The tool calculates the average vehicle speed from the vehicle speed of each vehicle type on the road location weighted by the proportion of AADTs of each vehicle type at the evaluated road location.

(9) ***Average vehicle speed of detour road section (unit: kilometers per hour):*** A tool user calculates the vehicle speed in the detour road section for each vehicle type and weights them by the proportion of distance for each of the road conditions (which have different vehicle speeds) along the detour road sections and inputs them in this tool. This tool calculates the average vehicle speed from the vehicle speed of each vehicle type on the detour road section weighted by the proportion of AADTs of each vehicle type at the detour road location.

(10) ***Average value of vehicle travel time savings in the evaluated road location (unit: currency per vehicle per hour):*** The value of travel time savings per vehicle (VTTS) refers to the unit benefits from reduced travel time costs per hour. For road geohazard damage involving vehicles, VTTS measures the unit loss due to increased travel time costs per hour. A tool user inputs the VTTSs for each vehicle type commonly used in a nation or region. This tool calculates the average VTTS from the VTTSs of each vehicle type weighted by the proportion of AADTs of each vehicle type at the evaluated road location.

(11) ***Average number of passengers of vehicles at the evaluated road location (unit: persons per vehicle):*** A tool user inputs the average number of passengers for each vehicle type either from (a) a country's traffic statistics, or (b) data of the nearest available traffic survey point along the road section. The operator (driver, conductor, and any assistant) is not included. This tool calculates the average number of passengers from the average number of passengers of each vehicle type at the road location weighted by the proportion of AADTs of each vehicle type at the evaluated road location.

(12) ***Average number of operators of vehicles at the evaluated road location (unit: persons per vehicle):*** "Operators" include drivers, conductors, and their assistants. A tool user inputs the average number of vehicle operators for each vehicle type either from (a) a country's traffic statistics, or (b) data of the nearest available traffic survey point along the road section. This tool calculates the average number of vehicle operators from the average number of operators of each vehicle type at the road location weighted by the proportion of AADTs of each vehicle type at the evaluated road location.

(13) ***Average number of passengers plus operators of vehicles at the evaluated road location (unit:*** persons per vehicle): This tool is processed by adding up the average number of passengers and the average number of operators for each vehicle type at the evaluated road location.

(14) Average price of new vehicles at the evaluated road location (unit: currency per vehicle): A tool user inputs the average price of a new vehicle for each vehicle type on the road using the country's commercial statistics. This tool calculates the average price of new vehicles from the average price of new vehicles for each vehicle type at the evaluated road location weighted by the proportion of AADTs of each vehicle type at the evaluated road location.

(15) Average value of a running vehicle at the evaluated road location (unit: currency per vehicle): A tool user inputs the average use years of the running vehicles (unit: years) and the annual value reduction percentage for each vehicle type (unit: percentage) from either commercial statistics or from the determined values by a public authority. This tool calculates the average value of a running vehicle using the following formula (Equation [B.2]):

(B.2) $$AVRVerl = APNVerl \times (1 - AVRPV)^{AUYRVerl},$$

where **AVRVerl =** average value of a running vehicle at the evaluated road location (unit: currency per vehicle);

APNVerl = average price of a new vehicle at the evaluated road location (unit: currency per vehicle);

AVRPV = annual value reduction percentage for vehicles (unit: percentage); and

AUYRVerl = average use year of running vehicles (unit: years).

2.2.2 Economic Loss Estimation

The economic loss section of Tool 2 shows required additional inputs and calculation procedures for the following economic loss components:

(1) Road infrastructure recovery cost (unit: currency): The road infrastructure recovery cost is the cost of the investment required to bring the damaged road infrastructure back to proper function. This includes not only permanent structures but also temporary roads, bridges or other temporary structures, and emergency remedial measures.

(2) Road interruption/disturbance traffic loss (unit: currency): In case of roadside-only damage or a partial-width closing, the tool automatically calculates the road disturbance traffic losses by inputting an "estimated number of days for road recovery from damage" and a "percentage of vehicle speed reduced due to damage" in addition to the traffic economics data inputs described earlier in Section 2.2.1, "Data Input for Traffic Economics."

In case of a whole-width road closing, as a simplified estimation, the "waiting loss" and "detour loss" are estimated, respectively, assuming either that all road users decide to wait for the road to reopen, or that all of the vehicles make an appropriate detour (smallest-loss detour). Then the lowest value between the "waiting loss" and the "detour loss" of all vehicles affected is selected as the road interruption traffic loss. The tool automatically calculates the road interruption traffic loss due to whole-width closing using the "estimated number of days for road recovery from damage of closure of the whole road width" in addition to the traffic economics data inputs described earlier in Section 2.2.1.

A detailed explanation of the additional inputs and the calculations are as follows:

- ***Road disturbance traffic loss due to roadside-only damage or partial-width road closing (unit: currency):*** A tool user inputs the probable number of days for recovery and the percentage of vehicle speed reduced by the damage, obtaining those data from the road management authority. The corresponding road management authority determines (a) the "estimated number of days for road recovery (unit: days)" from its experience of historically similar geohazard road damage cases; (b) the capacity of the road emergency recovery system, considering staffing, machinery, or standby contracts with private companies; and (c) the "percentage of vehicle speed reduced due to the potential damage (unit: percentage)" based on either its experience of historically similar geohazard road damage cases or on study results from entities such as a public research institute. The other values for the calculations were explained earlier in Section 2.2.1, "Data Input for Traffic Economics", and either entered by the tool user or processed automatically by the tool. The road disturbance traffic loss due to roadside-only damage or partial-width road closing is estimated using the following formulas (Equations [B.3], [B.4], and [B.5]):

  (B.3) **RDTL = ENVA x AIVTT x AVTTSerl**,

  (B.4) **ENVA = AADTerl x ENDR**,

  (B.5) **AIVTT = PERD/1,000/(AVSerl x(1 – PVSR)**,

  where **AIVTT =** average increase in vehicle travel time due to road damage at evaluated road location (unit: hours);

  AVSerl = average vehicle speed at evaluated road location (unit: kilometers per hour);

  AVTTSerl = average value of travel time savings of vehicles at evaluated road location (unit: currency per hour per vehicle);

  AADTerl = annual average daily traffic at evaluated road location (unit: vehicles per day);

  ENDR = estimated number of days for road recovery from damages (unit: days);

  ENVA = estimated number of vehicles affected by road damage (unit: vehicles);

  PERD = probable extension of road damage (unit: meters);

  PVSR = percentage of vehicle speed reduced due to damage (unit: percentage); and

  RDTL = road disturbance traffic loss (unit: currency).

- ***Waiting loss due to whole-width closing (unit: currency):*** A tool user inputs the estimated number of days for road recovery and the percentage of vehicle speed reduction due to the damage, obtaining those data from the road management authority. The corresponding road management authority determines (a) the estimated number of days for recovery from its experience of historically similar geohazard road damage cases, and (b) the capacity of the road emergency recovery system, considering staffing, machinery, or standby contracts with private companies. The other values for the calculations were explained earlier in Section 2.2.1, "Data Input for Traffic Economics," and either entered by the tool user or processed automatically by the tool. Then the road interruption traffic loss due to whole-width closing (unit: currency) is automatically calculated. The road interruption traffic loss adopts the lesser value between "waiting loss due to closure of whole road width (unit: currency)" and "detour loss due to the closure of the whole road width (unit: currency)."

- ***The "waiting loss due to whole-width closing" is estimated using the following formulas (equations [B.6], [B.7], and [B.8]):***

  (B.6) **WL_ww = ENVA_ww x AWT_ww x AVTTSerl**,

  (B.7) **ENVA_ww = AADTerl x ENDR_ww**,

  (B.8) **AWT_ww = ENDR_ww x 24/2**,

  where **AADTerl =** annual average daily traffic at the evaluated road location (unit: vehicles per day);

  AWT_ww = average waiting time of vehicles due to whole-width road closure (unit: hours);

  AVTTSerl = average value of vehicle travel time savings in the evaluated road location (unit: currency per hour);

  ENDR_ww = estimated number of days for road recovery from damage of whole-width road closure (unit: days);

  ENVA_ww = estimated number of vehicles affected by whole-width road closure due to road damage (unit: vehicles); and

  WL_ww = waiting loss due to whole-width road closing (unit: currency).

- ***The "detour loss due to closure" is estimated by using the following formulas (Equations [B.9] –[B.14]):***

  (B.9) **DL_ww = ENVA_ww x ALd_ww**,

  (B.10) **ENVA_ww = AADTerl x ENDR_ww**,

  (B.11) **ALd_ww = AIVOCd_ww + ALITT_ww**,

  (B.12) **AIVOCd_ww = AVOCdrs x Ddrs – AVOCers x Ders**,

  (B.13) **ALTTI_ww = AITTd_ww x AVTTSerl**,

  (B.14) **AITTd_ww = Ddrs/AVSdrs – Ders/AVSers**,

  where **AADTerl =** annual average daily traffic at evaluated road location (unit: vehicles per day);

  AITTd_ww = average increase in travel time for detour of vehicles due to whole-width road closure (unit: hours per vehicle);

  AIVOCd_ww = average increase in vehicle operating cost due to detour due to whole-width road closure (unit: currency per vehicle);

  ALITT_ww = average loss due to increase in travel time for detour of vehicles affected by whole-width road closure (unit: currency per vehicle);

  ALd_ww= average loss due to detour of vehicles affected by whole-width road closure (unit: currency per vehicle);

  AVOCdrs = average vehicle operating cost in the detour road sections (unit: currency per vehicle);

  AVOCers = average vehicle operation cost in evaluated road sections (unit: currency per vehicle);

  AVSdrs = average vehicle speed in the detour road section (unit: kilometers per hour);

  AVSers = average vehicle speed in the evaluated road section (unit: kilometers per hour);

  AVTTSerl = average value of travel time savings per vehicle at evaluated road location (unit: hours per vehicle);

Ddrs = distance of detour road sections, measured along the detour road sections between the origin and destination intersections with evaluated roads (unit: currency per vehicle);

Ders = distance of evaluated road sections, measured along the evaluated road sections between the origin and destination intersections with detour roads (unit: currency per vehicle);

DL_ww = detour loss due to whole-width closing (unit: currency);

ENVA_ww = estimated number of vehicles affected by whole-width road closure due to road damage (unit: vehicle); and

ENDR_ww = estimated number of days for road recovery from damage of whole-width road closure (unit: days).

(3) Human lives lost (unit: currency): A tool user inputs the "unit value of human lives lost" (unit: currency per person) and the "percentage of human lives lost to number of people affected by road damage event due to geohazard." These values should be determined by a national government or road management authority. A simplified evaluation procedure for the values is shown below.

- ***Unit value of human lives lost (unit: currency):*** The following formula provides a simple way to determine the unit value of human lives lost (Equation [B.15]):

  (B.15) UVHLL = GDP/Pop x ADL/2,

  where **UVHLL =** unit value of human lives lost (unit: currency);

  GDP = gross domestic product (unit: currency per year);

  Pop = population (unit: persons); and

  ADL = average duration of life (unit: years).

- ***Percentage of human lives lost to number of people affected by road damage event due to geohazard (unit: percentage):*** This percentage is determined by geohazard type and damage extent, studying the historical road damage caused by each geohazard type. It is determined by considering not only fatality but also causality. Table B.3 provides an example of an experimentally obtained value set.

Table B.3 Loss of Human Life Relative to Number of People Affected by Road Geohazard Damage (Example)

Type of road geohazard damage	Percentage of human lives lost to number of people affected by road geohazard damage
Bridge collapse of complete nonfunctionality	90
Roadside damage only	1
Half-width damage in total width of all traffic lanes	40
Whole-width damage in total width of all traffic lanes	80

The other values for the calculations, as explained earlier in Section 2.2.1 ("Data Input for Traffic Economics"), are either entered by the tool user or processed automatically by the tool.

- ***Human lives lost:*** The tool calculates the value of human lives lost (HLL) using the following formula (Equation [B.16]):

(B.16) HLL = UVHLL x NHAMRDEG x PHLL,

where **HLL =** human lives lost (unit: currency);

UVHLL = unit value of human lives lost (unit: currency per person);

NHAMRDEG = number of humans affected momentarily by a road damage event due to geohazard (unit: persons); and

PHLL = percentage of human lives lost to number of people affected by a road damage event due to geohazard (unit: percentage).

The "number of humans affected momentarily by a road damage event due to geohazard" **(NHAMRDEG) is determined by the following formula (Equation [B.17]):**

(B.17) NHAMRDEG = PERD/(AVSerl x 1,000) x (AADTerl/24) x ANP&Oerl,

where **NHAMRDEG =** number of humans affected momentarily by a road damage event due to geohazard (unit: persons);

PERD = probable extension of road damage (unit: meters);

AVSerl = average vehicle speed at evaluated road location (unit: kilometers per hour);

AADTerl = annual average daily traffic at evaluated road location (unit: vehicles per day); and

ANP&Oerl = average number of passengers and operators of a vehicle at evaluated road location (unit: persons per vehicle).

(4) Vehicle loss (unit: currency): A tool user inputs the percentage of vehicles lost relative to the total number of vehicles affected by a road damage event due to geohazard, which should be determined by the road management authority. A suggested procedure for this operations manual is shown below.

- ***Percentage of vehicles lost to number of vehicles affected by road damage event due to geohazard (unit:*** percentage): This percentage is determined by geohazard type and damage extent, studying the historical road damage caused by each geohazard type. Table B.4 provides an example of an experimentally obtained value set. The other values for the calculations, as explained earlier in Section 2.2.1 ("Data Input for Traffic Economics"), are either entered by the tool user or processed automatically by the tool.

Table B.4 Percentage of Vehicles Lost to Number of Vehicles Affected by Road Geohazard Damage (Example)

Road geohazard event type	Percentage of vehicles lost to number of vehicles affected by road geohazard damage
Bridge collapse of complete nonfunctionality	90
Roadside damage only	1
Half-width damage in total width of all traffic lanes	40
Whole-width damage in total width of all traffic lanes	80

• ***Vehicle loss (unit: currency):*** The tool provides the following formulas to calculate vehicle loss (VL) (Equation [B.18]):

(B.18) VL = AVRVerl x NVAMRDEG x PVL,

where **AVRVerl =** average value of a running vehicle at evaluated road location (unit: currency per vehicle);

NVAMRDEG = number of vehicles affected momentarily by a road damage event due to geohazard (unit: vehicles); and

PVL = percentage of vehicles lost to number of vehicles affected by a road damage event due to geohazard (unit: percentage).

The tool provides the following formula to calculate the number of vehicles affected momentarily by a road damage event due to geohazard (NVAMRDEG) (Equation [B.19]):

(B.19) NVAMRDEG = PERD/(AVSerl x 1000) x (AADTerl/24),

where **NVAMRDEG =** number of vehicles affected momentarily by a road damage event due to geohazard (unit: vehicles);

PERD = probable extension of road damage (unit: meters);

AVSerl = average vehicle speed of evaluated road location (unit: kilometers per hour); and

AADTerl = annual average daily traffic at evaluated road location (unit: vehicles per day).

The other values for the calculations, as explained previously in Section 2.2.1 (“Data Input for Traffic Economics”), are either entered by the tool user or processed automatically by the tool.

(5) Other loss (unit: currency): Other losses should also be included in case considerable responsibility is attributable to the road management authority (for example, if roadside buildings are affected or agricultural land is damaged by a road embankment collapse).

2.3 Estimation of Risk and Risk Measures Benefit

Reference: Tool 3: Estimation of Potential Annual Economic Loss and Cost-Benefit Analysis for Geohazard on a Road Location; Sheet 1: Estimation of Potential Annual Economic Loss and Benefit of Measures on a Road Location

Tool 3, Sheet 1, “Estimation of Potential Annual Economic Loss and Benefit of Measures on a Road Location”, is formulated to be used by anyone with access to the required data for the potential annual loss estimation. All data to be entered shall be studied by engineering geology, hydrology, or hydraulic engineering experts and authorized by the corresponding road managing authority.

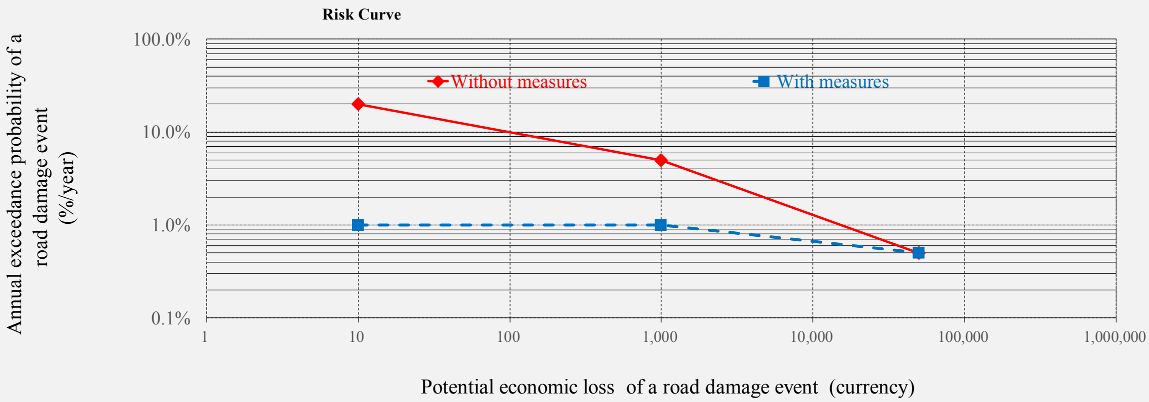
2.3.1 Usage Instruction and Explanation

In Tool 3, Sheet 1 (Figure B.11), the white cells are for users’ input; the gray cells show instruction or results calculated by the tool.

Figure B.11 *Tool 3, Sheet 1: Estimation of Potential Annual Economic Loss and Benefit of Measures on a Road Location*

Tool 3: Estimation of Potential Annual Economic Loss and Cost - Benefit Analysis for Geohazard on a Road Location
Sheet 1: Estimation of Potential Annual Economic Loss and Benefit of Measures on a Road Location

	white color cell is for users' input		gray colored cells include instruction or results calculated by this tool		
Location ID		Road Name			
Station Origin		Station Destination		Extension along road (m)	



With/Without measures (Investment for road geohazard risk management)	Damage level	Symbol of variables	Calculation formula	Potential disaster events of different road damage extent. Note: If only one level of extent is inputted, the same values shall be inputted for all columns of magnitude level 1, 2, and 3. If two levels of magnitude are used, the lower level goes on the first column and the other value shall be inputted for both columns of magnitude level 2, and 3.	extent level 1	extent level 2	extent level 3
				Description of damage extent level	roadside only damage	Partial width road closing 1 lane	whole width road closing total 2 lanes
Same value of with/without measures	Potential economic loss of different road damage extents (currency/event)	ELp			10	1,000	50,000
Without measures implemented	Occurrence probability in years of different road damage extents (years)	Yp_oM	-		5.0	20.0	200.0
	Annual exceedance probability of different road damage extents (%/year)	AEP_oM	= 1/Yp_oM		20.0%	5.0%	0.5%
	Potential annual economic loss of a road location (currency/year)	AELp_oM	= Integral computation of ELp and their AEP_oM, or ELp x AEP_oM of a road damage extent				1,473
With measures implemented	Design target occurrence probability in years for a road location (years)	DTYp	-				100.0
	Occurrence probability in years of different road damage extents (years)	Yp_wM	If DTYp > Yp_oM, Yp_wM= DTYp, otherwise Yp_wM=Yp_oM		100.0	100.0	200.0
	Annual exceedance probability of different road damage extents (%/year)	AEP_wM	= 1/Yp_wM		1.0%	1.0%	0.5%
	Potential annual economic loss on a road location (currency/year)	AELp_wM	= Integral computation of ELp and their AEP_wM, or ELp x AEP_wM of a road damage extent				378
Annual benefit of geohazard risk measures on a road location (currency/year)		ABGRR	= AELp_oM- AELp_wM				1,096

2.3.2 Explanation of Each Input and Calculation of Economic Risks and Benefits

2.3.2.1 Data Input

In Tool 3, Sheet 1, users should enter the data where required (in the white cells) as follows:

- ***Potential economic loss of different road damage extents (unit: currency per event):*** See the data preparation procedure as explained earlier in Section 2.2, "Economic Loss Estimation."
- ***Occurrence probability in years of different road damage extents (unit: years):*** See the data preparation procedure as explained earlier in Section 2.1, "Evaluation of Occurrence Probabilities."
- ***Design target occurrence probability in years for a road location (unit: years):*** This is the target-occurrence probability in years of no geohazard damage-causing events on a road location when road geohazard risk management measures are in place. This tool evaluates the occurrence probability in years and estimates the potential economic loss for different extents of damage ("roadside-only damage," "partial-width closing," and "whole-width road closing"). The measures increase the occurrence probability in years (unit: years) and correspondingly decrease their inverse value, the annual exceedance probability (unit: percentage per year) of a road damage event. On the other hand, the value of an economic loss (unit: local currency) is fixed for each road damage extent on a road location; there are no differences between the economic losses of a road damage extent for the scenario without implemented measures and those for the scenario with their implementation. This tool proposes design target occurrence probability (in years) settings for the cost-benefit analysis pertaining to two geohazard types, as further discussed below: (a) fall, collapse, or slide-type geohazards; and (b) river erosion and flow-type (hydrological) geohazards.

Fall, collapse, and slide-type geohazards. Road slope stabilization measures and protection measures for road damage risk from slide-type geohazards are designed as permanent measures (assuming appropriate maintenance throughout the road´s life-span). Structural measures are designed to obtain adequate safety factors of slope stability (resistance force against slope failure). The design safety factor for slope stability is changed based on the importance of the hazard-prone road location and the viability of the investments for geohazard risk measures. The safety factor of the slope stability design and target occurrence probability in years of no geohazard-causing damage events on a road location are experimentally set as shown in Table B.5 or the following equation:

DTOP = 500 x (DSF -1),

Where **DTOP:** Design target occurrence probability value on a road location (years); and

DSF: Design safety factors of slope stability.

Slope drainage and vegetation (bioengineering) also affect the slope stability experimentally, but they cannot be considered among the safety factors for the slope stability. This tool proposes that when only (a) slope drainage measures, (b) only vegetation measures, or (c) a combination of both are planned, the design target occurrence probability in years of a road location can be set as follows: (a) half of the drainage design capacity rainfall return period (for the effect of slope drainage); or (b) two years (for the effect of slope vegetation).

Road structures to protect against fall or collapse type-geohazards (such as rockfall or soil collapse) are designed with bigger protection capacity against the assumed maximum-impact forces or energy considering a safety factor. The value of the design target "occurrence probability in years on a road location" is set to "100" (100 years), taking into account the occurrence of unexpected impact-force or energy events.

Table B.5 Proposed Design Target Occurrence Probability (in Years) on a Road Location for Slope Stability Measures (Example)

Design target occurrence probability value on a road location (years)	Design safety factors of slope stability (resistance force against slope failure) [a]	Road importance (road type) [b]
100	1.20	Urban, interurban, paved, high-volume traffic
75	1.15	
600	1.12	Rural, unpaved, low-volume traffic
50	1.10	
25	1.05	

a. "Slope failure" encompasses slope fall, collapse, or slide.

b. The "road importance (road type)" categories are those proposed by this handbook.

River erosion and flow-type (hydrological) geohazards. The measures for river erosion and flow-type geohazards (such as flood or earth or debris flow) are planned or designed using hydrological or hydraulic analysis. In such analysis, especially of flooding and rainfall extents, the concept of return period (unit: years) is used, which means the same as the occurrence probability in years (unit: years). The term "return period" can be applied because the extents of river erosion and flow-type geohazards have a recurrent property in clear correlation with the extent of rainfall. Measures to reduce the risk of flow-type geohazards are planned by setting the control targets based on the return period for an extent of flow-type geohazards that can be addressed safely without causing any road damage. For example, road-crossing waterways are planned to meet adequate flow capacity; retarding facilities such as retarding basins are planned to reduce the peak flow volume and meet the flow capacity of road-crossing waterways; and river erosion protections are planned to meet hydraulic requirements depending on the return period of geohazard flow. The "design target occurrence probability in years" is set equal to the design return period of the flow-type geohazard.

Landscape ecosystem conservation works (for example, riverbed erosion protection and reforestation of landscape ecosystem) have an indirect effect on the risk measures of road damage against river erosion and flow-type geohazards. Hence, when considering such measures, there is no established procedure for setting the design target occurrence probability in years. In experiments, two to five years can be set as a value, based on expert judgment.

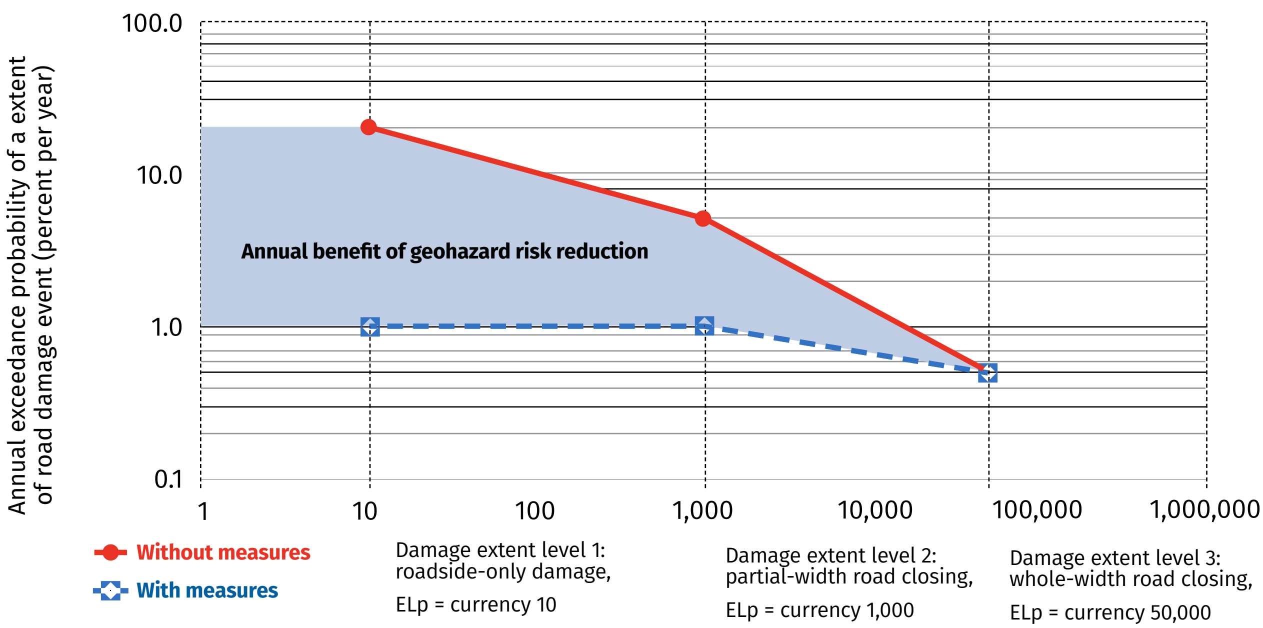
2.3.2.2 Calculation of Economic Risk and Benefit

- ***Potential annual economic loss of a road location without measures implemented (unit: currency per year):*** This is a road damage risk index, measured by anticipated average economic loss on a road location in a year. "Without measures" refers to the situation verified during the risk evaluation inspection. Regardless of whether effective or ineffective measures are in place, the situation is treated as "without measures" for the comparison study between the current situation and the scenario with new planned measures. The potential annual loss reflects both elements of probability and extent for geohazard damage events on a road location.

A road location has different sets of geohazard damage extents (for example, "roadside-only damage," "partial-width road closing," and "whole-width road closing") and their corresponding probabilities of damage event. The procedure for estimating risk as potential annual economic loss is an integral computation of the sets of different extents of annual exceedance probabilities (unit: percentage per year) and their economic losses for road damage events (unit: currency) due to geohazards on a road location. To simplify the estimation, a manipulation of an annual exceedance probability (unit: percentage per year) and its economic loss for a road damage event can be used. The annual exceedance probability is the chance or probability of an event happening annually (unit: percentage per year); it is the inverse value of the occurrence probability in years (unit: years).

Figure B.12 illustrates the calculation chart of potential annual economic losses without measures, namely the risk curves, which are derived from the plots of annual exceedance probabilities of road damage event occurrence (on the vertical axis) and potential economic loss of road damage events (on the horizontal axis). The potential annual loss is indicated for areas through the integral computation of the area between the risk curve and the axis.

Figure B.12: Economic Risk Curve of Road Geohazard Damage on a Road Location



Note: ELp = Potential economic loss.

- ***Potential annual economic loss on a road location with measures implemented (unit: currency per year):*** This loss is calculated using the same concept as that of the loss without measures in place. For the calculation, occurrence probability in years with measures in place is set by using the design target occurrence probability in years (unit: years) for a road location. If the occurrence probability in years without measures is smaller than the design target occurrence probability in years, the probability values "with measures" are set equal to the design target occurrence probability in years. Otherwise, they are set equal to the occurrence probability in years "without measures." Then an integral computation result of the sets of different extents of annual exceedance probabilities with measures (the inverse of the occurrence probability in years with measures) and their economic loss for road damage events is the potential annual economic loss for a road location with measures.
- ***Annual benefit of geohazard risk measures on a road location (unit: currency per year):*** The benefit can be estimated using the difference between the potential economic annual losses with and without geohazard risk measures implemented. The annual benefit of geohazard risk measures is indicated as the area between the risk curves for the scenario without measures and the scenario with measures and the vertical axis (Figure B.12).

2.4 Cost-Benefit Analysis

Reference: Tool 3: Estimation of Potential Annual Economic Loss and Cost-Benefit Analysis for Geohazard on a Road Location; Sheet 2: Cost-Benefit Analysis for Geohazard Measures on a Road Location

Tool 3, Sheet 2, "Cost-Benefit Analysis for Geohazard Risk Measures of a Road Location," is formulated to be used by anyone with access to the required data for the potential annual loss estimation, as described in this section. All input of data shall be studied by experts in engineering geology, hydrology, hydraulic engineering, and civil engineering, and the data should be authorized for use by the corresponding road managing authority.

2.4.1 Usage Instruction and Explanation

In Tool 3, Sheet 2 (Figure B.13), users enter the required data only in the white cells.

2.4.2 Explanation of Each Input and Cost-Benefit Analysis Result

2.4.2.1 Data Input

- ***Investment cost for road geohazard risk measures (unit: currency):*** The planners of road geohazard risk measures (experts in engineering geology and civil engineering) prepare a conceptual design with a rough cost estimation to meet the design target occurrence probability in years.
- ***Annual maintenance cost for measures installed (unit: currency per year):*** The planners of the road geohazard risk measures also estimate the annual maintenance costs, such as the costs to repair or replace structure materials or to remove sediments from flood or debris control dams.
- ***Discount rate (unit: percentage):*** The discount rate and the evaluation period for the cost-benefit analysis are set to the usual values used for road infrastructure investments in the particular country or region where the tool is being used.

2.4.2.2 Calculation of Cost-Benefit Analysis

The tool calculates the net present value, benefit-cost ratio, and economic internal rate of return after the user has input the data described above.

Figure B.13: Tool 3, Sheet 2: *Cost-Benefit Analysis for Geohazard Risk Measures of a Road Location*

Tool 3: Estimation of Potential Annual Economic Loss and Cost - Benefit Analysis for Geohazard on a Road Location

Sheet 2: Cost-Benefit Analysis for Geohazard Measures on a Road Location

[ ] white color cells are for users' input [ ] gray colored cells include input names, instructions or results calculated by this tool

Project Name					
Location ID		Road Name			
Station Origin		Station Destination		Extension along road (m)	

Investment for road geohazard measures (cost input)

No.	Work	Unit	Quantity	Unit Price (currency)	Amount (currency)
1	Subsurface drainage drilling	LS	1	290	290
2	Ground anchor	LS	1	3,700	3,700
3					0
4					0
5					0
6					0
7					0
Investment Cost (IC)					**3,990**
Annual maintenance cost				**AMC**	**20**

Annual benefit of investment of geohazard measures: expectation of annual average economic loss reduction

Item	Symbol of variables	Quantity (currency)
Potential annual economic loss without measures implemented (currency/year)	AELp_oM	1,473
Design target occurrence probability in years (years)	DTYp	100.0
Potential annual economic loss with measures implemented (currency/year)	AELp_wM	378
Annual benefit of geohazard risk reduction (currency/year• •	ABGRR	1,096

Cost-Benefit Analysis (evaluation term is 20 years)

Discount rate (percentage)		12%
Net present value (currency)	**NPV**	4,045
Benefit cost ratio	**BCR**	1.98
Economic Internal rate of return (percentage)	**EIRR**	13%

Calculation table of cost-benefit analysis

Year	Age of measures	Discount rate	Investment cost in a year (currency)	Annual maintenance cost in a year (currency)	Expectation of annual average economic loss reduction (currency / year)	Net benefit of a year	Net present value of a year
	age	DR	IC	AMC	EAAELR	NB=(EAAELR-IC-AMC)	NPV= $NB/(1+DR)^{age}$
2016	0	12%	3,990	0	0	-3,990	-3,990
2017	1	12%		20	1,096	1,076	960
2018	2	12%		20	1,096	1,076	858
2019	3	12%		20	1,096	1,076	766
2020	4	12%		20	1,096	1,076	684
2021	5	12%		20	1,096	1,076	610
2022	6	12%		20	1,096	1,076	545
2023	7	12%		20	1,096	1,076	487
2024	8	12%		20	1,096	1,076	434
2025	9	12%		20	1,096	1,076	388
2026	10	12%		20	1,096	1,076	346
2027	11	12%		20	1,096	1,076	309
2028	12	12%		20	1,096	1,076	276
2029	13	12%		20	1,096	1,076	247
2030	14	12%		20	1,096	1,076	220
2031	15	12%		20	1,096	1,076	197
2032	16	12%		20	1,096	1,076	175
2033	17	12%		20	1,096	1,076	157
2034	18	12%		20	1,096	1,076	140
2035	19	12%		20	1,096	1,076	125
2036	20	12%		20	1,096	1,076	112
Net present value		**NPV**	3,990	149	8,185	4,045	**4,045**
Benefit Cost ratio		**BCR**					**1.98**
Economic Internal rate of return		**EIRR**					**13%**

CONTACT

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GFDRR is a global partnership that helps developing countries better understand and reduce their vulnerabilities to natural hazards and adapt to climate change. Working with over 400 sub-national, national, regional, and international partners, GFDRR provides grant financing, technical assistance, training, and knowledge sharing activities to mainstream disaster and climate risk management in policies and strategies. Managed by the World Bank, GFDRR is supported by 37 countries and 11 international organizations.

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The World Bank Tokyo Disaster Risk Management (DRM) Hub supports developing countries to mainstream DRM in national development planning and investment programs. As part of the Global Facility for Disaster Reduction and Recovery, the DRM Hub provides technical assistance grants and connects Japanese and global DRM expertise and solutions with World Bank teams and government officials. The DRM Hub was established in 2014 through the Japan-World Bank Program for Mainstreaming DRM in Developing Countries – a partnership between Japan's Ministry of Finance and the World Bank.

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