TERMS OF REFERENCE
FOR
"CONDUCTING LANDSLIDE RISK ASSESSMENT IN BHUTAN"
REFERENCE NO: BT-DOST-MOIT-383277-CS-QCBS
STRENGTHENING RISK INFORMATION FOR DISASTER RESILIENCE IN BHUTAN

A. PROJECT BACKGROUND AND OBJECTIVES

Bhutan is highly vulnerable to hydro-meteorological and seismic hazards, including flooding, landslides, glacial lake outburst floods (GLOFs), earthquakes, cloudbursts, windstorms, and forest fires, as a result of its geographical location and varied topography. Floods and landslides significantly threaten people's lives, assets, and infrastructure every monsoon. Between 1994 and 2016, some 87,000 people were affected, and over 380 deaths occurred due to natural disasters in Bhutan. In 2009, Cyclone Aila brought unprecedented rainfall and floods, affecting farmland and infrastructure with damages of approximately US$17 million (1.2 percent of GDP). In 2009 and 2011, Bhutan was struck by two high-magnitude earthquakes that caused losses of US$52.6 million[1] (4.3 percent of GDP) and US$24.5 million[2] (1.4 percent of GDP), respectively. The floods of 2016 washed away settlements in the southern parts of the country. They destroyed critical infrastructure, including roads and bridges, cutting away the upper parts of the country from food and fuel supply.

According to the International Panel on Climate Change (IPCC), some regions have significantly increased trends in heavy precipitation events. IPCC states that "there is high confidence that changes in heat waves, glacial retreat, and/or permafrost degradation will affect high-mountain phenomena such as slope instabilities, landslides, and glacial lake outburst floods. There is also high confidence that changes in heavy precipitation will affect landslides in some regions"[3]. In the case of Bhutan, the situation is further aggravated by seismic activity.

Landslides are "the movement of a mass of rock, debris or earth down a slope"[4,5]. Landslides are triggered by slope saturation with water, seismic or volcanic activity, and, more recently, GLOFs. Landslides that begin as saturated soils can rapidly turn to high-debris avalanches and high-velocity debris and mud flows that flow into highly populated areas in the lower valleys.

Though landslides are a natural occurrence, landslides can be instigated, or the environment can be primed for landslides by deforestation, unplanned development, and encroachment of

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[1] RGOB, World Bank, and UN. 2009. Bhutan Earthquake September 21, 2009: Joint Rapid Assessment for Recovery

[2] RGOB, World Bank, and UN.2011. Bhutan Earthquake September 18, 2011: Joint Rapid Assessment for Recovery

[3] IPCC, WMO, UNEP. (2012). "Managing the risks of extreme events and disasters to advance climate change adaptation: Special Report of the International Panel of Climate Change", P.83, 126, 175-190

[4] The International Geotechnical Societies' UNESCO **Working Party on World Landslide Inventory** (WP/ WLI) was formed for the international decade for Natural Disaster Reduction (1990 to 2000).

[5] 2008. US Department of Interior and US Geological Survey, "The landslide Handbook: A Guide to Understanding Landslides"

habitation into high-risk areas. In many developing countries, the construction of roads in river basins and mountainous regions can destabilize the terrain, leading to higher vulnerability to landslides and higher erosion and sedimentation rates.

Bhutan faces challenges managing its landslide risks due to rugged terrain, the fragile geology of the Himalayan mountains, and the heavy annual monsoon. This project will support (i) Reviewing existing records and building a database of past landslide events, (ii) conducting a landslide hazard and risk assessment of Bhutan applying a climate and seismic vulnerability, (iii) defining the methodology for conducting detailed monitoring and mitigation of landslide hazard by analyzing specific hotspot areas through the use of drones and remote sensing, and (iv) Capacity development of the Department of Surface Transport (DoST) engineers and other relevant stakeholders to carry out monitoring, mitigation, and landslide risk assessments as a way forward.

Furthermore, Bhutan needs help in effectively implementing its policy framework for integrating climate and disaster risk management into development activities. The system is plagued by limited data availability, insufficient technical capacity, and coordination issues, hindering decision-making and risk assessment efforts. Moreover, the absence of a comprehensive and accessible disaster risk information system, compounded by scattered and inaccessible data, has resulted in duplication of efforts and inefficient resource utilization.

To tackle these issues, The Royal Government of Bhutan (RGOB) aims to develop a Multi-Hazard Risk Decision Support System (MHRDSS) as a common platform for risk information and decision-making. The MHRDSS will integrate risk information into development planning, providing improved tools for risk assessment. The project involves a nationwide multi-hazard risk assessment, focusing on high-risk hazards like earthquakes, floods, and landslides. It will acquire the necessary data and maps to develop a comprehensive risk information database. The MHRDSS platform will be user-friendly, promoting stakeholder coordination in disaster risk management and development. The work performed under this ToR will contribute to the landslide data and maps for the MHRDSS.

By implementing the MHRDSS, Bhutan aims to enhance its risk-informed decision-making capacity and integrate risk information into planning and development processes. This comprehensive approach will lead to more effective disaster risk management, reduced duplication of efforts, and efficient allocation of resources to address climate and disaster risks. Ultimately, the MHRDSS will enable Bhutan to understand better and mitigate the impacts of natural hazards, safeguarding its people's lives, assets, and infrastructure. This landslide risk assessment will feed into the overall MHRDSS that is currently being developed in parallel to this consultancy assignment.

B. Objective of Consultancy

The main objective of the proposed ToR is to develop a comprehensive understanding of landslide hazards and risks in Bhutan to inform the prioritization of future climate and seismic resilient investments in slopes in Bhutan.

The objective will be achieved by (i) Reviewing existing records and building a database of past landslide events, (ii) conducting a landslide hazard and risk assessment of Bhutan applying a climate and seismic vulnerability, (iii) To conduct detailed monitoring and mitigation of landslide hazard by analyzing specific hotspot areas through the use of drones and remote sensing, and (iv) Capacity development of the Department of Surface Transport (DoST) engineers and other relevant stakeholders to carry out monitoring, mitigation, and landslide risk assessments as a way forward.

C. General Scope of the Service

The general scope of this service is as follows:

The proposed project adopts a systematic approach to assist the Government of Bhutan by determining the hazards and risks due to landslides triggered by future climate and seismic events. The scope covers the entire country. The consultant shall identify and map the risks of landslides affecting the various sectors (e.g., transport, energy, industrial, and agricultural) and how they impact the security of all the different population settlements. The risk analysis on various sectors will perform a more detailed analysis of landslide hazard and risk assessment in the transport sector.

The consultant shall identify and integrate existing landslide databases to develop a national comprehensive landslide database. The consultant will also assess the impacts of these hazards and identify the hot spot areas, which are the locations with the most significant impact due to landslides. Once the priority hotspots are identified and agreed upon with the client, the consultant shall perform detailed site-specific risk assessments. Subsequently, the consultant will identify possible monitoring, mitigation, and/or resilience interventions for the identified hotspots, prepare indicative cost estimates, and prepare a cost-benefit analysis for each intervention alternative for each hotspot. The consultant shall perform capacity development of DoST engineers to ensure the products developed from the consultancy are utilized and implemented beyond the consultancy period to inform the prioritization of future climate and seismic resilient investments in slopes in Bhutan.

D. DELIVERABLES/SPECIFIC OUTPUTS EXPECTED FROM CONSULTANT

1. Inception report
2. A comprehensive national landslide inventory (that includes seismic and rainfall-induced landslides) with location, landslide type, type of trigger, date of the event, and source. A Geographic Information System (GIS) database with the following information:
    i. datasets for susceptibility, hazard, and risk analysis triggered by rainfall and seismic-induced landslides.
    ii. datasets for landslide exposure analysis for various sectors, with a special focus on the transport sector.

3. Report and GIS layers of drone and remote-sensing-based monitoring and mitigation of hotspot areas.
4. Road network vulnerability, criticality, and risk assessment report
   i. Network criticality assessment and recommendation report.
   ii. Network risk assessment report.
5. Risk management and mitigation plan for the national road network (Report)
6. Training of trainers and capacity building of Government of Bhutan technical staff on landslide risk assessment for sustainability of interventions.
7. Final report and transmission of the final inventory
8. Final Workshop

Specification to Deliverables

1. **<u>Inception report</u>**

The Inception Report summarizes the proposed methodological approach and the proposed study plan, a review of the existing datasets prepared by the DoST, the Department of Geology and Mines, other relevant government agencies, and academia to be submitted within one (1) month of the commencement of the assignment. There will be a kick-off meeting in Bhutan in week 2 or 3 of the project. The minutes of the kick-off meeting shall be included in the inception report.

2. **<u>Landslide inventory (database with the following information)</u>**

Data Standards and Transfer Media

Tabular data must be provided in a readily accessible or well-known format. This includes, but is not limited to, CSV, tab-delimited text files, or Microsoft Excel spreadsheets. Additional formats may be used with approval. Currently, Bhutan uses open-source data collection systems like Kobo. The consultant should evaluate the use of this system for the comprehensive landslide database and make recommendations for improvement if needed.

Geospatial data must include details of projection and must be provided in a standard OGC (Open Geospatial Consortium) format or well-known format. The minimum requirements to be followed for all geospatial (GIS) data are:

Metadata: Detailed documentation needs to be provided for each data set. This metadata must include description, source, contact, date, accuracy, and restrictions. A description of attributes needs to be provided for vector and tabular datasets. There are available ISO standards commonly used by World Bank projects to guide the development of metadata;

Vector data: Geospatial vector data must be provided in a standard OGC format or well-known format. This includes but is not limited to ESRI shapefile, KML, GML, WKT, and

Raster data: Geospatial raster data must be provided in a standard OGC or another well-known format. This includes but is not limited to GeoTIFF, JPEG, JPEG2000, ERDAS IMG, ArcInfo ASCII, Binary grid, and MrSid.

2.1 Data for susceptibility, hazard, and risk analysis triggered by rainfall and seismic-induced landslides.

2.1.1 Update/modify datasets as necessary for landslide susceptibility, hazard, and risk analysis for Bhutan.

2.1.1.1 Activities:

1. Collect and QA/QC landslide input datasets. This will include, but is not limited to, a cleaned historical landslide events data, Seismic and hydrological induced landslides that generated events in historical times with information on activity level, and identification of different types of landslides prevailing in the area. This will include reviewing previous work done in the matter where landslides registered in the country have already been collected and compiled but mainly use satellite imaging techniques to identify past events that enable enlarging the existing database. Review and see the possibility of improving soil, geological, and land use maps of Bhutan, more accurate DEM developed since the last study undertaken, and any additional information that could be of use for conducting a landslide susceptibility analysis.

2. Update and modify landslide input datasets to ensure the datasets are as complete as possible, adding landslide events from different research and previous studies conducted in the region.

3. Develop a tailor-made methodology for landslide susceptibility, hazard, and risk analysis based on the data availability for the region. Examine and propose options for improving the existing physically-based approach and compare it with the results of a new susceptibility analysis based on a probabilistic methodology utilizing machine learning and deep learning algorithms.

4. Develop a technical report describing how the approaches adopted for landslide susceptibility, hazard, and risk analysis can sum up, list their limitations, and provide recommendations on how these datasets could be progressively improved through time and the resources necessary to do this.

2.1.1.2 Expected Outputs:

1. A technical report describing the data collected, the methodology adopted, its limitations, and recommendations to improve datasets progressively through time.
2. Datasets required for landslide susceptibility, hazard, and risk analysis.
3. Geological maps:
    i. Digitization of geological maps to be used for analysis.
    ii. Soil type identification if the data for the soil of the regions are available.
    iii. Land-use and landcover maps.
    iv. Geomorphology of an area if available.
    v. Digital elevation models.
    vi. Soil and rock geotechnical properties.
    vii. Groundwater information
    viii. Available borelogs

2.1.1.3 Methodology and Results:

- Processing of available digital elevation models for deriving different parameters, which will be used for landslide susceptibility analysis.
- Comparisons of results of different available DEMs and their impact on analysis.
- Susceptibility analysis based on biased statistical techniques and ground truthing.
- Field verified and historical events ad-on landslide susceptibility resultant maps for the region.

2.1.2 Update/modify datasets as necessary for use in landslide hazard assessment.

2.1.2.1 Activities:
1. Collect and QA/QC earthquake and rainfall input datasets. This will include, but will not be limited to, a cleaned historical rainfall and earthquake catalogue, seismic sources (fault lines and area sources) that generated events in historical times with information on activity level, depth, and traces, other seismic sources (e.g., Identified fault lines), strong ground motion records, micro-zonation studies, shear wave analysis, GPS strain measurements, etc.

2. Update and modify earthquake input datasets as necessary to ensure the datasets are as complete as possible, including the potential addition of global datasets such as GEM Faulted Earth, earthquake catalogues from other geophysical monitoring agencies (e.g., literature Survey; Ambraseys Eq. catalogue, India Meteorological Department, USGS, etc.).

3. Collect and integrate ancillary hazard data from various stakeholders, including: Surface soil and geology maps, micro-zonation studies, and digital elevation data (topographical maps).

4. Develop a technical report describing the data collected and their limitations and provide recommendations on how these datasets could be progressively improved through time and the necessary resources.

2.1.2.2 Expected Outputs:
1. All databases and catalogues that form inputs into PSHA, including primary datasets, value-added and QA/QC'ed datasets. These will include:

Seismic Source Model:

a. Geo-referenced fault database with associated attributes based on existing information (including activity level, depth and traces, representative slip behavior, and any recurrence information);
b. Consistent, statistically complete earthquake catalogue (Mw, earthquake recurrence and maximum magnitude).
c. Development of Frequency-Mag. (G-R) relationships
d. Active Deformation, if available

Ground Motion Model:

e. Strong Ground Motion Data and justification of the selection of Ground Motion Model based scientific debate and consensus
f. Crustal velocity structure information

Site Response Model:

g. Maps of near-surface geology (site classes)
h. Shear wave velocity for the top 30 m of geology (Vs30) – proxies can be used if no shear wave analysis exists
i. Micro-zonation studies
j. Other dynamic soil properties such as shear modulus and damping ratio for possible site amplification analysis when available.

2. A technical report describing the data collected, its limitations, and recommendations to improve datasets progressively through time.

2.2 Datasets for landslide exposure analysis for various sectors, with a special focus on the transport sector.

2.2.1 Activities:

1. Collect all existing exposure data related to transport infrastructure assets (including but not limited to information on the number of lanes, road type, bridges, drains, street lights, and road signs) on the national road network for Bhutan. The scale of these datasets should be appropriate to the scale of the risk assessment – and the scale should be decided in collaboration with stakeholders after sieving initial data availability.

2. Calibrate existing hazard, exposure, and vulnerability data for Bhutan.

3. Input all geospatial data layers into the database, including appropriate metadata that meets relevant ISO standards.

4. Develop a technical report systematically documenting the vulnerability curves and recommendations to improve these input variables over time.

2.2.2 Expected Outputs:

1. A technical report that describes:
   a. The transport infrastructure topologies on the national road network
   b. The vulnerability curves with detailed mathematical formulas (e.g., asset-based vulnerability curves, population-based vulnerability curves) for each infrastructure topology.

2. Geo-spatial data layers for each exposure aspect outlined above – including appropriate metadata.

2.2.3 National Scale landslide hazard and risk assessment.

2.2.3.1 Objectives:

1. Using state-of-the art earthquake risk modeling methodology and datasets compiled in earlier components, undertake:
   i. Probabilistic Seismic Hazard Assessment and Risk Analysis for the study area
   ii. Deterministic Seismic Impact Analysis for the study area

2. Using state-of-the rainfall/run-off modeling methodology and datasets compiled in components undertake:
   i. Identify critical rainfall patterns that trigger landslides
   ii. Determine for each landslide the annual probability of being triggered

3. Using state-of-the art landslide hazard and risk modeling methodology and datasets compiled in components undertake:
   i. Probabilistic Landslide Hazard Assessment and Risk Analysis for the study area
   ii. Deterministic Impact Analysis for Bhutan
   iii. Model verification with a few recent landslides

4. From the analysis in 1 and 2, determine the most vulnerable sections of the road network as well as impacts on transportation infrastructure assets. From the analysis in 3 identify vulnerable zones, roads and infrastructure as well as impacts on transportation.

2.2.3.2 Activities:

1. Using an earthquake hazard and risk modeling software and datasets compiled undertake the following analysis:
   a) Probabilistic Seismic Hazard Assessments with at least three relevant different return periods.
   b) Probabilistic Seismic Risk Analysis for Bhutan – looking at the risks to the exposure assets collected under activity 2b. This should have an aim of determining the most 'at risk' assets and undertake quantitative analysis of the potential fatalities and financial loss.
   c) Deterministic Impact Analysis for assessing resilience against earthquakes in the area.

2. Using state of the art hydrology modeling software and datasets compiled in above components, undertake the following analysis:
   a) Probabilistic hydrologic and hydraulic analysis of rainfall runoff and river hydraulics. Undertake Subsurface flow modeling to determine probability of failure.
   b) Using the rainfall-induced hazard results, determine the impacts to the exposure assets. This should have an aim of determining the most 'at risk' buildings and transportation assets with the analysis of the potential population affected.

3. Using landslide hazard and risk modeling software and datasets compiled undertake the following analysis:
   a) Probabilistic landslide Hazard Assessments triggered by earthquake and rainfall for the selected return periods.

b) Probabilistic landslide Risk Analysis – looking at the risks to the exposure assets collected under activity 2b. This should have an aim of determining the most ‘at risk’ assets and undertake quantitative analysis of the potential fatalities and financial loss.

c) Deterministic Impact Analysis for assessing resilience against landslide.

2.2.3.3 Methodology:

The Consultant shall elaborate on the proposed methodology in the detailed technical proposal.

2.2.3.4 Expected Outputs:

1. Technical report describing the methodologies and results of the analysis described above.
2. GIS layers of the outputs of the hazard and risk analysis.

3. **Report and GIS layers of drone and remote-sensing-based monitoring and mitigation of hotspot areas.**

   Evaluate suitable drone-based photogrammetry and satellite-based InSAR and/or other remote sensing methods for monitoring landslide hot-spot areas with some of the highest risks to the communities and critical infrastructure. Demonstrate the value of the monitoring and develop a monitoring plan and transfer the technology to the DoST technical staff for long-term sustainability.

Expected Outputs:

1. A report summarizing the remote sensing-based monitoring of landslide risk in hot-spot areas.
2. Detailed manual for technology transfer.
3. Geospatial data layers for the various aspects of the monitoring.

4. **Road Network Vulnerability, Criticality and Risk Assessment Report**

4.1 Network Criticality Assessment Report

1. Develop a transport network model that will be used as a basis for the criticality and vulnerability analysis. The transport system model will include all roads in Bhutan (national and sub-national). This study zone will ensure airport access, hydropower station access roads, health services access roads, main tourism destinations, passenger vs. freight corridors, agriculture clusters, border crossings, and roads that will become the main routes for traffic diverted due to the disruption of national highways. It will include traffic data and commodity flow in and out of the major ports.
2. Simulate disruption of primary road network links. This task will use the transport network model to disrupt links of the road network one by one.
3. Evaluate performance metrics for each disruption scenario. For each of the simulations run in the previous activity, performance metrics of choice (e.g., total economic cost, user cost,

days of disruption, business disruption cost…) will be calculated to evaluate the change in performance and the criticality of each link.

4. The criticality results of a link will be a combination of its importance under no disruption scenarios (item 1 above), worsening performance metric when disrupted (activity 3), and exposure to hazards e.g., landslides

4.1.1 Expected outputs:

1. Network criticality results for the national road network in geospatial and tabular format.
2. Maps displaying network criticality results.

4.2 Network Risk Assessment

4.2.1 Objectives: To quantify the vulnerability and risk of the network based on user cost and disruption due to landslide impacts.

4.2.2 Activities:

1. Calculate the decrease in network performance metrics due to landslides under (i) current condition and (ii) future traffic and climate change scenario. The performance of the transport system will be calculated, incorporating the information available on increasing landslide risks due to climate change impacts, using the same performance metrics used in the previous task. The system's vulnerability to future scenarios will be identified by comparing new and baseline metrics.
2. Perform quantitative risk assessment, both in terms of indirect impacts (using the network performance metrics) and direct asset damages, due to landslide events. The values from the network performance model will inform the risk assessment for rainfall- and seismic-induced landslide hazard events.

4.2.3 Expected Outputs:

1. Network vulnerability and risk results for the national road network in geospatial and tabular format.
2. Maps displaying network vulnerability and risk results.

5. <u>Risk Management Plan for the National Road Network (Report)</u>

5.1 Objectives: To identify climate-resilient/mitigation interventions for hotspots on Bhutan's national road network. Quantify the cost and benefits of different climate-resilient interventions.
Priority climate resilient intervention for most critical and vulnerable segments.

5.2 Activities:

1. Perform an initial exploratory analysis of potential interventions to reduce the vulnerability of the transport system. Perform a review that will include potential intervention on Bhutan roads to minimize the impact of climate change, including increased redundancy with secondary roads or landslide monitoring and mitigation interventions.

2. Evaluate economic analysis of different interventions at hot spot areas. The vulnerability, criticality analysis, and socio-economic network impact will be compared to the projected cost of interventions to evaluate their cost-effectiveness and potential regret. The consultant is expected to identify cost-effective interventions and increase the transport system's resilience.
3. Identify and prioritize interventions in the Bhutan road system to reduce vulnerabilities and future risks. The Consultants will utilize the principles of Decision Making Under Deep Uncertainty methodologies. These decision support methodologies are designed to help develop robust and flexible plans. These methods seek to understand better how decision makers' options perform under a wide range of conditions, rather than under a single or handful of predicted conditions. The consultant must identify which input conditions best explain when each intervention meets or fails to meet decision makers' performance thresholds. They are also expected to identify tipping points in the uncertain factors that will make each option fail to reach its objectives. These conditions will describe scenarios to which each option is vulnerable.

5.3 Expected Outputs:

1. List of priority interventions to increase the resilience of the national road network
2. Cost benefit analysis of selected interventions

6. Training of Trainers and Capacity building

6.1 Training of Trainers (TOT)

6.1.1 Objectives:

1. To assess the existing technical capacity of the DOST officials in conducting landslide risk assessment
2. To develop a short-term (by June 2025) and a medium-term TOT plan and a TOT curriculum based on the technical capacity gap assessment metioned above
3. To train the technical people on hazard and risk assessment processes.
4. To assess and guide technical staff on the futuristic technical needs for conducting and uploading climate hazard and risk assessment studies
5. To orient DOST staff on the sustainability of processes adopted for climate hazard and risk assessments

6.1.2 Activities:

Assess the existing technical capacity of the DOST officials in conducting landslide risk assessment and develop a short-term (by June 2025) and a medium-term TOT plan and a TOT curriculum based on the results of the assessment. Conduct hybrid/local workshops, seminars, and training to demonstrate and orient technical audience on the following activities:

1. How to conduct probabilistic seismic and rainfall induced landslide hazard assessment.
2. How to conduct landslide susceptibility and risk analysis.
3. How to do risk modeling and parameter selection for data constraint environments
4. Tech transfer on how to utilize drone and remote sensing-based approaches for hot-spot monitoring.

In the training component of this project, it is crucial to emphasize and prioritize continuous training for officials under DoST and other relevant stakeholders. This approach involves training sessions scheduled at regular intervals or each time a milestone or deliverable is completed. The objective is to ensure that trainees thoroughly understand the overall process and and become trainers of other DOST staff in the future. Regular training sessions will empower officials to maintain a comprehensive and up-to-date grasp of the project, thereby enhancing their performance and preventing the accumulation of undue pressure on resources as the project progresses. Engage DOST staff in the delivery of Tasks 1-5 for hands-on training as much as possible.

6.2 Training Report

Report with all training manuals, materials, training plans, a capacity gap assessment report, and awareness materials. Videos and post-training surveys including stakeholder feedback based on the OECD's evaluation criteria[1] and lesson-learned recommendations for future training.
The awareness materials shall be in the form of easy-to-understand community maps discussed in training and improved based on stakeholder feedback.

7. Final Report and transmission of final inventory

7.1 Activities:

Develop a final report that articulates the following:

1. Description of input datasets and models used in this study, their limitations and recommendations for improving these datasets with time and resources. This includes the vulnerability models, replacement costs, loss data, etc.
2. Development of the landslide susceptibility, hazard, and risk assessment for Bhutan, including assumptions, justification of modeling choices, and uncertainty description.
3. Results of all the analysis.
4. Upload all datasets, analyses, and results that were used, developed, or resulted from this study into the database. This also includes the development of metadata and output files, in line with the guidance provided in this document.

8. Final Workshop

Undertake a Final Workshop with the stakeholders to share the risk assessment results. This should include producing dissemination material such as brochures with results and illustrative material (e.g., visuals, hazard maps, risk maps) informing various stakeholders of the risk results.

Schedule with Summary of Task and Deliverables

Sl.No	Task/Deliverables	Schedule
1	Inception Report	Within 1 month from the signing of the contract

[1] https://www.oecd.org/dac/evaluation/daccriteriaforevaluatingdevelopmentassistance.htm

2	A comprehensive national landslide inventory	3rd Month
3	Report and GIS layers of drone and remote sensing-based monitoring and mitigation of hotspot	5th Month
4	Road network vulnerability, criticality and risk assessment (Report)	7th Month
5	Risk Management and Mitigation Plan for National Road Network (Report)	8th Month
6	Training report (technical capacity gap assessment report, a training plan, a TOT curriculum, and a post-training survey)	9th Month
7	Final Report	11th Month
8	Final Workshop	12th Month

E. PERIOD OF CONTRACT

The overall period of the contract will be 12 months.

F. SPECIAL TERMS & CONDITIONS / SPECIFIC CRITERIA

The interested consultants shall be an international management consultancy firm incorporated for at least five (5) years for offering similar services and have completed similar projects of this scale and complexity.

Consulting firm should:

1. Possess sound knowledge of the workings of the Government of Bhutan, as well as of all concepts, principles, and approaches required for the assignment;
2. Have prior working experience in similar geographical conditions (hilly regions);
3. Demonstrate that they have enough capacity (including personnel) to handle similar assignments by providing organizational structure and details of technical resources.
4. Make every effort to partner with a firm in Bhutan to ensure effective data collection and in-country capacity building.
5. Propose an adequate approach, methodology, and work plan for timely and effective assignment completion.
6. This technical assistance assignment will require the firm to staff an appropriate mix of highly qualified international and local staff. An example of possible key team members may include several, but not necessarily limited to the staff noted below. Where key experts proposed by firms do not have experience in the South Asia region, they are expected to hire experts with such experience in the region to assist the key experts. It is up to the firm to propose which of the staff on its team is Team Leader and Deputy Team Leader, among the positions: Senior Economist, Senior Road Engineer, and Disaster Risk Assessment Specialist, and Geotechnical Engineer. The individuals (Team

Leader and Deputy Team Leder) should be spread in a way to be available all through the assessment period and will have overall responsibility for the direction, technical excellence, and successful completion of the project and should have 15 years of Project Management experience and leadership qualities in addition to the requisite qualifications of one of the key staff positions noted below.

Key Experts

Key Staff	Qualifications	Duration (man-months) for each key expert	Experience
Senior Economist	Master's degree in Economics required, PhD preferred	3 months	12 years of experience in micro-economics. Experience with statistical modeling; designing, implementing household, commercial properties, etc. surveys; and performing complex econometric analysis strongly preferred. 3 years of experience in similar studies, preferably in the South Asia region.
Senior Road Engineer	1st degree in civil engineering, with a post-graduate qualification in roads-related discipline. Full membership of national or international professional institution	3 months	20 years or more experience in road engineering, out of which a minimum of 7 years post-graduate experience in roads and drainage design, preferably in the South Asia region, would be an advantage. Some CCA and/or DRM-related project experience preferred
Disaster Risk Assessment Specialist/ climate change specialist	Bachelor's degree in Civil Engineering, Urban Planning, Geology, or other relevant Disaster Management subject is required, as well as a relevant postgraduate qualification.	3 months	He/she should have 15 years of experience in natural disaster assessment, mitigation, and remediation, at least 5 of which should be with a developing country or emerging nation, preferably in the South Asia region.

GIS/Mapping Specialist/ Remote Sensing Expert	Bachelor of Science or Engineering Degree required	6 months	10 years of GIS experience and experience working with various data formats such as CAD, GPS, etc. Knowledge of environmental resource management, transportation, or geography is strongly preferred.
Geotechnical engineer	At a minimum, a Bachelor's degree in science or engineering discipline (Biology, Chemistry, Geology, Civil or Chemical Engineering)	12 months	15 years of experience in positions requiring proficiency with the analysis and application of environmental regulations; skills in applying environmental and technical concepts are also required—at least 5 years' experience in similar studies, preferably in the South Asia region.

G. Implementation Arrangements

The Consulting Firm will work closely with the DOST and will report to the DOST regularly.

The Project Manager of the Consulting Firm will be the principal contact and will be expected to be readily available during project implementation. The Consulting Firm shall be responsible for all aspects of service performance as outlined in this TOR's components.
The working language for this project shall be English for communication with the DOST and its consultants. All final deliverables shall be in English.

H. Data Standards and Transfer Media

Tabular data must be provided in a readily accessible or well-known format. This includes, but is not limited to, *CSV, tab-delimited text files, or Microsoft Excel spreadsheets*. Additional formats may be used with approval.

Geospatial data must include projection details and be provided in a standard OGC or well-known format. The minimum requirements to be followed for all geospatial (GIS) data are:

1. Metadata: Detailed documentation needs to be provided for each data set. This metadata must include description, source, contact, date, accuracy, and restrictions. A description of attributes needs to be provided for vector and tabular datasets. There are available ISO standards commonly used by World Bank projects to guide the development of metadata;
2. Vector data: Geospatial vector data must be provided in a standard OGC format or well-known format. This includes but is not limited to ESRI *shapefile, KML, GML, and WKT*.

3. Raster data: Geospatial raster data must be provided in a standard OGC or another well-known format. This includes but is not limited to GeoTIFF, JPEG, JPEG2000, ERDAS IMG, ArcInfo ASCII, Binary grid, and *MrSid*.

Licensing

Results procured and developed for this project are done on behalf of the Royal Government of Bhutan. Usage shall be guaranteed to the Royal Government of Bhutan; therefore, all licensing agreements must be made similarly. The license includes the right of the RGoB to freely use and distribute the results, through the following means:

1. Hazard, risk and environmental assessments;
2. Research into the natural and built environment;
3. Extraction of derivatives (including, but not limited to, slope and roughness) and features (including, but not limited to, building footprints, fault traces and other geomorphic features). Extracted derivatives and features will be the intellectual property of whoever extracts them;
4. Presentation in reports and presentations;
5. Presentation, distribution and analysis through the internet; and

Dissemination of spatial hazard and loss data (shapefiles and rasters) in national data management platforms.

Selection Procedure: the consultant will be selected following Quality and Cost Based Selection (QCBS) method as set forth in the World Bank Procurement Regulations for IPF Borrowers, November 2020.