



National Building Research Organisation
Ministry of Irrigation and Water Resources & Disaster Management



REDUCTION OF LANDSLIDE VULNERABILITY BY MITIGATION MEASURES PROJECT



COST-BENEFIT ANALYSIS

Financial Assistance



ASIAN INFRASTRUCTURE
INVESTMENT BANK

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Detail Cost-Benefit Analysis for 23 additional Landslide Sites

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BACKGROUND

It is the responsibility of the project implementing agency for assessing cost and benefit associated with each stage of the landslide mitigation project finance by the Asian Infrastructure Investment Bank (AIIB). The purpose of cost benefit analysis in the project is to have a systemic approach to figure out the pluses and minuses of various paths through a project, including transactions, tasks, and investments. Government of Sri Lanka (GoSL) planned for an estimated total investment of USD 104 million in three years (January 1, 2019 - December 31, 2022) and has dispense a budget for USD 97 million for Civil works and associated designs and construction supervision/management for landslide mitigation with the financial support of the Asian Infrastructure Investment Bank (AIIB). Project objective is to improve the landslide risk management effort of the country by introducing required mitigation measures and thereby, redress the present situation of high risk imposed on vulnerable communities and infrastructure. The project will benefit 12000 population vulnerable for landslides in identified project locations.

PROJECT DESCRIPTION

Occurrence of landslides, slope failures and rock falls and their reactivation have become a frequent natural phenomenon in Sri Lanka attracting more and more attention due to its impact on human and economic loss. Many of the natural hill slopes that are considered as safe in the past are now recording landslides due to human interventions. According to the available records, nearly 1000 human lives were lost while over 300,000 people were made homeless and many infrastructure facilities including highways, dams, railway track, hospitals, schools and other public & private building were damaged. In May 2017, 35 major landslides occurred causing the major number of deaths from the disaster events, 176 out of 219. In this background, National Building Research Organisation (NBRO) is signed an agreement with the Asian Infrastructure Investment Bank (AIIB) to obtain funding assistance for mitigating/rectifying unstable slopes in high risk areas in 11 districts of 06 provinces of Sri Lanka. The project will execute mitigation measures to protect the key infrastructures, such as the railway network, highways, roads, water supply and electricity network and communication system. Intension of these mitigation measures are to ensure the safety of communities from frequent catastrophes cause by landslides.

There are three main category of mitigation measures broadly identified.

- Category - 1: Deals with improvement of drainage to drain away the water from slide area.
- Category - 2: Related to slope modifications to increase the stability of the slope.
- Category - 3: Landslide control measures for long term stabilization of the slope.

PROJECT SCOPE

Based on the current recorded information, the indicated below are the project components with its respective estimated cost: (source: PMU, NBRO)

- **Component 1:** Civil works (construction) with associated designs and construction supervision/management activities, for 147 landslide sites (including the sites along the roads and railway). The estimated cost of USD 97.0 million.
- **Component 2:** Policy, Regulation Enhancement and Project Implementation Support, at estimated cost of USD 6.0 million.
- **Component 3:** Provision of essential laboratorial equipment for NBRO, at estimated cost of USD 1.0 million.

PROJECT DURATION AND OVERALL COST

The implementation period of the project is expected to be 4 years, at total estimated cost of **USD 104 million**.

IMPLEMENTATION STRATEGY

The project would be implemented into 2 phases:

Phase I will include 27 landslide sites in critical conditions, which will be designed and prepared for bidding by NBRO in-house staff, with some externally recruited specialists, for which procurement process must start immediately. The Mission was informed that out of these 27 sites, the detailed designs for 4 sites have been already completed and the Detailed Project Reports (DPR) have been ready to be incorporated into related Bidding Documents. As soon as the environmental and social aspects (site-specific ESMPs) are prepared and incorporated, it is expected that the Bids for these 4 sites will be issued within 2 months from to date.

Phase II will include:

- i) Preparation of detailed designs and bidding documents and assistance to procurement of contractors for the remaining 120 landslides, and
- ii) Supervision on construction.

This consulting assignment will be carried out by a qualified consulting firm/s, based on Quality and Cost procurement selection procedures, for which NBRO has started to prepare a draft TOR.

AIMS AND OF OBJECTIVES OF THE PROJECT

The proposed project aims to improve the landslide risk management effort of the country by introducing required mitigation measures and thereby, redress the present situation of high risk imposed on vulnerable communities and infrastructure.

This project target to

- (i) Mitigate selected landslides and unstable slopes
- (ii) enhance capacity of NBRO to effectively deal with landslide mitigation efforts,
- (iii) Introduce and regularize the best land use practices and construction/ development guidelines for landslide prone areas, and
- (iv) Enhance public awareness on landslide mitigation.

COST-BENEFIT ANALYSIS FOR THE PROJECT

Cost-Benefit analysis (CBA), sometimes called cost benefit analysis (CBA), is a systematic approach to estimate the strengths and weaknesses of alternatives (for example in transactions, activities, functional business requirements or projects investments); it is used to determine options that provide the best approach to achieve benefits while preserving savings. The CBA is also defined as a systematic process for calculating and comparing benefits and costs of a decision, policy (with particular regard to government policy) or (in general) project.

Broadly, CBA has two main purposes:

- To determine if an investment/decision is sound (justification/feasibility) - verifying whether its benefits outweigh the costs, and by how much;
- To provide a basis for comparing projects - which involves comparing the total expected cost of each option against its total expected benefits.

CBA is related to (but distinct from) cost-effectiveness analysis. In CBA, benefits and costs are expressed in monetary terms, and are adjusted for the time value of money, so that all flows of benefits and flows of project costs over time (which tend to occur at different points in time) are expressed on a common basis in terms of their net present value.

27 LANDSLIDE SITES IN CRITICAL CONDITIONS

Phase I will include 27 landslide sites in critical conditions, which will be designed and prepared for bidding by NBRO in-house staff, with some externally recruited specialists, for which procurement process must start immediately. The Mission was informed that out of these 27 sites. List of sites as follows;

Site No	Province	District	DS	GN	Village/Location
1	Central	Kandy	Gangawata korale	Dangolla	Circular road, Jumma Masjid Avenue
2	Central	Kandy	Kundasale	Gonawala North	Digana, Gonawala
3	Sabaragamuwa	Rathnapura	Ayagama	Ayagama	Ayagama town
4	Western	Kalutara	Bulathsinhala	Niggaha	Pahiyangala Temple, Bulathsinhala
5	Sabaragamuwa	Kegalle	Ruwanwella		(B445) Veyangoda - Ruwanwella Road
6	Sabaragamuwa	Kegalle	Dehiovita	Dikalla	4km Post- (B093) Dehiovita - Deraniyagala - Nooriya road (LHS)
7	North Western	Kurunegala	Polgahawela	Ganegoda South	Polgahawela bus stand
8	Sabaragamuwa	Kegalle	Aranayaka	Narangala	LHS of Aranayaka- Hulankapolla road
9	Sabaragamuwa	Kegalle	Bulathkohopitiya	60D, Puspane	Vilubahene, In between 17\3 and 17\4 culverts
10	Sabaragamuwa	Kegalle	Dehiovita	Dikalla	(B093) Dehiovita-Deraniyagala-Nooriya road, in between 5/11 and 5/13 culvert
11	Sabaragamuwa	Kegalle	Kegalle	51G, Meepitiya	RHS of Bypass road
12	Western	Colombo	Seethawaka	Kaluaggala	Kaluaggala
13	Sabaragamuwa	Rathnapura	Kalawana	Kalawana	Kalawana Town
14	Sabaragamuwa	Rathnapura	Kalawana	Kalawana	Kalawana Gamini Central college
15	Sabaragamuwa	Rathnapura	Nivithigala	Peboutuwa	Thiriwanaketiya - Agalawatta Road, In between culvert No.26/9and 26/10
16	Sabaragamuwa	Rathnapura	Rathnapura	Thirivanaketiya	A4 road, In between Culvert No. 105/3 and 105/4(Katandola)
17	Sabaragamuwa	Rathnapura	Ratnapura	Durekkanda	Durrekkanda
18	Sabaragamuwa	Rathnapura	Ratnapura	Galabada	Galabada
19	Southern	Matara	Akurassa	Nimalawa	Semidel gowipala kanda
20	Sabaragamuwa	Kegalle	Kegalle	Ranwala	Kegalle Court Complex
21	Southern	Matara	Pitabeddara	Rambukana West	Galle - Madampe road at 57/4 culvert
22	Southern	Matara	Kotapola	Thenipita	Galle – Deniyaya – Madampe Road at 77+050 -77+450
23	Uva	Badulla	Bandarawela	Bandarawela West	Thepalkanda
24	Uva	Badulla	Haliela	Uduwara	7 th mile post, New Colony, Uduwara
25	Sabaragamuwa	Kegalle	Ruwanwella	Thumbaliyadda	(B445) Veyangoda - Ruwanwella Road 23+100 - 23+210 (RHS)
26	Western	Kalutara	Baduraliya	Athweltota	Landslide near Athwelthota Gangarama
27	Western	Kalutara	Walallawita	Lihiniyawa	Sri Abhinawarama Viharaya

23 ADDITIONAL LANDSLIDE SITES FOR COST BENEFIT ANALYSIS

Further detail cost benefit analysis of the project, it is selected additional 23 landslide sites for the detailed cost benefit analysis. List of additional 23 landslide site locations are as follows;

S/N	Site No	Province	District	DS	GN	Village/Location
1	29	Central	Kandy	Pathahewawahata	Oluwawatte	Oluwawatte, Marassana
2	30	Central	Kandy	Udadumbara	Kalalgamuwa	Kalalgamuwa
3	37	Central	Matale	Rattota	Rattota	Raththota Public Playground
4	42	Central	Nuwara Eliya	Ambagamuwa	Samanalagama	Samanalagama - Hatton
5	52	Sabaragamuwa	Rathnapura	Kalawana	Koswattha	Kalawana - Rakwana Road, In between culvert No.2/4and 2/5(Koswattha),
6	60	Sabaragamuwa	Rathnapura	Nivithigala	Nivithigala	Nivithigala Town
7	61	North Western	Kurunegala	Mallawapitiya	745, Walpolakanda North	Walpolakanda North Upper Colony
8	63	Central	Kandy	Udawalpaya	Doragala	Chapley Division
9	68	Sabaragamuwa	Kegalle	Mawanella	Dumbuluwawa Sinhalagama	Dumbuluwawa
10	69	Central	Matale	Matale	Dodamdeniya	Dodamdeniya
11	84	Western	Kalutara	Dodangoda	722 A, East Serupita	Isipathana Mahamewna Asapuwa
12	87	Western	Kalutara	Millaniya	655A, Ballanthudawa	Sri Shaila Pushpakaramaya temple
13	88	Western	Kalutara	Panadura	687 - C, Wekada North	Sri Nagahananda Viharaya, 75, Fonseka Road, Panadura
14	91	Central	Kandy	Gangawatakorale	Udaperadeniya	Galendawatte
15	120	Central	Nuwara Eliya	Walapane	Wewakele	51/5- 51/7(RHS) culverts on the B413 road
16	125	Uva	Badulla	Welimada	Koskanuwegama	99/7-99/8 culverts on the A005 road
17	127	Uva	Badulla	Welimada	Koskanuwegama	100/3-100/6 culverts on the A005 road
18	128	Sabaragamuwa	Kegalle	Rambukkana	Godagandeniya	Rambukkana-Kadigamuwa, CH 53+75 (LHS)
19	129	Sabaragamuwa	Kegalle	Rambukkana	Kadigamuwa	Kadigamuwa Railway Station, CH 55+45 (RHS)
20	137	Central	Nuwara Eliya	Nuwara Eliya	Thalawakele	(Approaches of tunnel no 15 from both sides) Between Kotagala (111/25) and Thalawakele (115/72), CH 115/37 - 115/40 and 115/52 - 115/57
21	139	Uva	Badulla	Welimada	Ohiya	At Ohiya station
22	145	Uva	Badulla	Bandarawela	Inikam Bedda	Between Diyathalawa (156/54) and Bandarawela (160/36), Ch 160/00 - 160/22
23	147	Uva	Badulla	Ella	Madhuragama	Between Ella (168/14) and Demodara (171/47), Ch 168/55 - 168/60

METHODOLOGY

Cost-benefit and related project appraisal approaches are applied in seeking to secure the highest return to investment. Cost Benefit Analysis (CBA) is an appropriate method for the assessment of the economic efficiency of the Disaster Risk Reduction measures. CBA is methodologically complex and should be seen as a decision facilitator rather than the sole criterion for decision making. Costs and benefits associated with a project are estimated by comparing the situation that would hold with and without the project and then expressed in monetary terms. It provides a decision-making tool for comparing scenarios with or without landslide mitigation in place. Integrating risk-based methods into cost-benefit approaches makes it possible to consider the impacts of landslide mitigation by quantifying their likely economic consequences.

Cost-benefit analysis consist following steps;

Step 1: Initial data collection in 147 landslide mitigation project sites: Cost-benefit analysis was initiated with initial data collection on 147 landslide mitigation project sites. Initial data collection includes; District, Divisional Secretariat Division, location, potential damages, approximate area liberate by landslide mitigation, type of landslide, status of landslides and proposed landslide mitigation measures.

Step 2: Drone survey and detail data collection in 27 critical sites: Drone survey and detail data collection in 27 critical sites was the next step. Drone provide a quick, safe and potentially superior means of inspecting large scale, remote and difficult to access landforms with significant cost benefits compared to traditional inspection methods. Simple applications of UAV involve real time or post viewing of footage and still photographs of the study area. Primary data was collected at the site using online application.

Step 3: Detail benefit calculation of 27 critical sites: Detail project benefit analysis was carried out in 27 landslide mitigation project sites. Project benefit analysis calculated in 27 critical sites includes; costing for human lives, cost of using alternation roads, costing for building replacement, costing for road debris clearance, costing for road repairing, possible costing saved by the project on infrastructure such as electricity, water supply provisions.

Step 4: Drone survey and detail data collection in 23 additional sites: Drone survey and detail data collection in 23 additional sites was conducted. Drone provide a quick, safe and potentially superior means of inspecting large scale, remote and difficult to access landforms with significant cost benefits compared to traditional inspection methods. Simple applications of UAV involve real time or post viewing of footage and still photographs of the study area. Primary data was collected at the site using online application.

Step 5: Detail benefit calculation of 23 additional sites: Additional to 27 critical sites, as per the requirement, detail project benefit analysis was carried out in additional 23 landslide mitigation project sites. Project benefit analysis calculated in 23 additional sites includes; costing for human lives, cost of using alternation roads, costing for building replacement, costing for road debris clearance, costing for road repairing, possible costing saved by the project on infrastructure such as electricity, water supply provisions.

Step 6: Benefit value calculation for 97 sites: Benefit value calculation for 97 sites includes other sites (28-117), sites proposed by Road Development Authority and sites proposed by Sri Lanka Railways. Benefit value calculation for these sites were calculated from the experience acquired from 27 critical sites and additional 23 additional sites. Assumptions on benefits were made including; houses protected, liberation area by mitigation, length of roads protected, infrastructure such as electricity, water supply protected, lives saved, length of railway line protected, rail passenger income loss saving, and railway station replacement cost saving etc.

Step 7: Presentation of the Cost-benefit analysis result of 147 sites: Cost-benefit analysis is presented by dividing the landslide mitigation project costs through the landslide mitigation project benefits. In this step, project benefit value was calculated for 147 sites includes; 27 critical sites, additional 23 sites, other sites (76), sites proposed by Road Development Authority (7 site and sites proposed by Sri Lanka Railways.

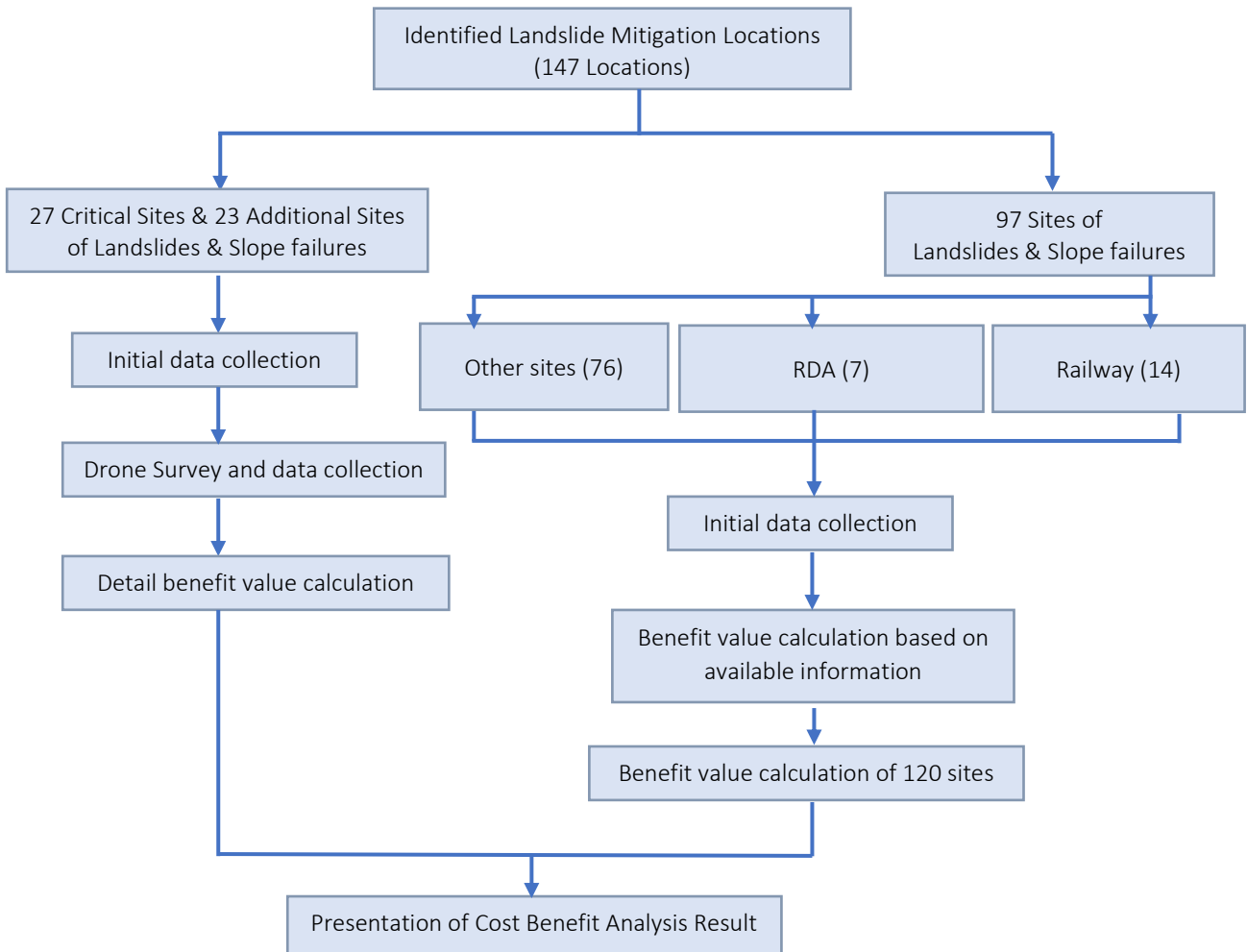
Accordingly benefit value as follows;

- 27 critical sites - LKR 7,644,209,110.00
- 23 additional sites - LKR 7,402,086,600.00
- Other sites (76 sites) - LKR 7,331,961,628.33
- Sites proposed by Road Development Authority (7 sites) - LKR 321,500,000.00
- Sites proposed by Sri Lanka Railways (14 sites) - LKR 865,200,000.00

Cost for landslide mitigation project - USD 104,000,000.00 (LKR 16,848,000,000.00)

USD conversion rate - LKR 162.00

Methodology adopted for cost-benefit analysis of 147 landslide mitigation site is depicted in following diagram



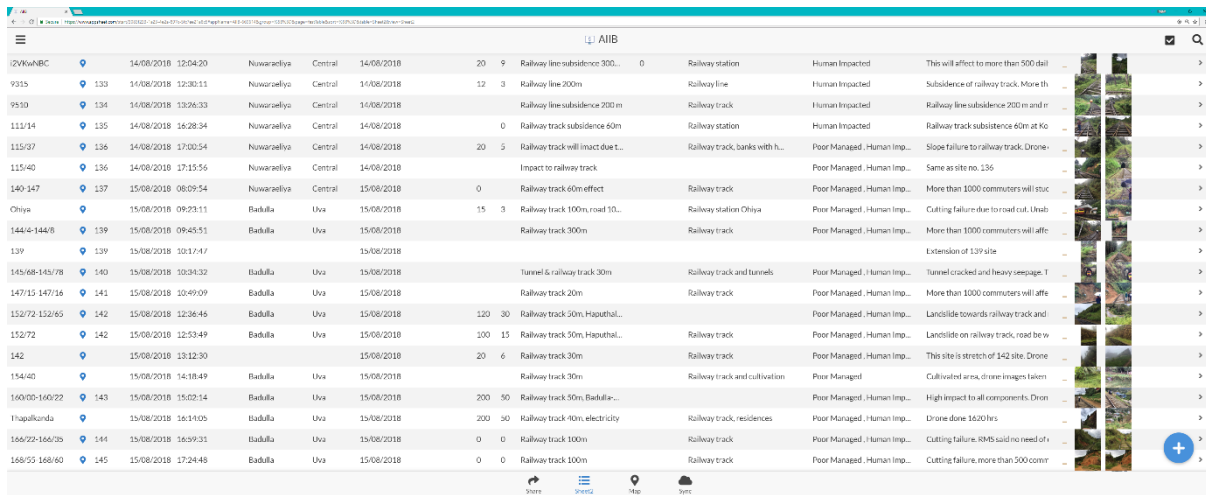
DATA COLLECTION METHOD

Drone survey and data collection had been done for the 27 sites to detail the landslide mitigation sites. Drone survey had been proceeded to develop Orthomosaic images, Keyhole Markup Language (kml) and Digital Surface Model (DSM) of the location. With these outputs its help to develop mosaic image, 3D model, contours and cross sections to demarcate the clear representation of the site.

Data had been collected by using online application “AppSheet”. “AppSheet” is an app maker that makes it easier for everyone to develop custom Android and iOS apps even without any coding experience. It allows developing apps directly from the data and makes it possible for beginners to create and deploy apps in less time.

This online database helps to;

- Monitor the progress online and on time
- Ability to data collection on site
- Data storing and store in supportive platform



i2VKwNBC		14/08/2018	12:04:20	Nuwaraeliya	Central	14/08/2018
9315	133	14/08/2018	12:30:11	Nuwaraeliya	Central	14/08/2018
9510	134	14/08/2018	13:26:33	Nuwaraeliya	Central	14/08/2018
111/14	135	14/08/2018	16:28:34	Nuwaraeliya	Central	14/08/2018
115/37	136	14/08/2018	17:00:54	Nuwaraeliya	Central	14/08/2018
115/40	136	14/08/2018	17:15:56	Nuwaraeliya	Central	14/08/2018
140-147	137	15/08/2018	08:09:54	Nuwaraeliya	Central	15/08/2018
Ohiya		15/08/2018	09:23:11	Badulla	Uva	15/08/2018
144/4-144/8	139	15/08/2018	09:45:51	Badulla	Uva	15/08/2018
139	139	15/08/2018	10:17:47			15/08/2018
145/68-145/78	140	15/08/2018	10:34:32	Badulla	Uva	15/08/2018
147/15-147/16	141	15/08/2018	10:49:09	Badulla	Uva	15/08/2018
152/72-152/65	142	15/08/2018	12:36:46	Badulla	Uva	15/08/2018
152/72	142	15/08/2018	12:53:49	Badulla	Uva	15/08/2018
142		15/08/2018	13:12:30			15/08/2018
154/40		15/08/2018	14:18:49	Badulla	Uva	15/08/2018
160/00-160/22	143	15/08/2018	15:02:14	Badulla	Uva	15/08/2018
Thapalkanda		15/08/2018	16:14:05	Badulla	Uva	15/08/2018
166/22-166/35	144	15/08/2018	16:59:31	Badulla	Uva	15/08/2018
168/55-168/60	145	15/08/2018	17:24:48	Badulla	Uva	15/08/2018

Preview of the Resettlement Site Data-Base as shown in Computer



COST-BENEFIT ANALYSIS ASSUMPTIONS & LIMITATIONS

Element no.	Human lives		
Costing for Human lives			
01	Value per human life (LKR)	100,000.00	<i>Death Compensation Value - National Natural Disaster Insurance Policy - NITF</i>
Buildings			
Costing buildings			
02	All buildings are considered as same type and with unique features Property Cover up value per building (LKR)	2,500,000.00	<i>NITF</i>
Roads			
For the cost of using alternation roads			
03	Vehicle fuel efficiency	10 km per liter	<i>Ceypetco</i>
04	Fuel rate (LKR)	150.00	
05	Traffic rates	One lane design with vehicle carrying capacity of 15,000 vehicles per day	
06	C & D class roads (consider 1 lane)	1,000 vehicles per day	<i>RDA</i>
07	B class road (consider 2 lanes)	30,000 vehicles per day	<i>RDA</i>
08	A class road (consider 2 lanes)	30,000 vehicles per day	<i>RDA</i>
09	No. days to clear debris on road	10 days	
Road debris clearance			
10	Cost of debris clearance (LKR)	LKR 1200/m2	<i>Local authority</i>
Road repairing			
		Cost (Rs/m2)	
11	Road (carport)	15,000.00	<i>RDA</i>
12	Road (Tar)	2,000.00	<i>RDA</i>
Railway			
13	Construction of railway line (LKR) - Per Meter	480,000.00	<i>Sri Lanka Railways</i>
14	Rail passenger ticket income (Colombo-Kandy) - Per passenger	500.00	<i>Sri Lanka Railways</i>
15	Rail passenger ticket income (Colombo Nanuoya, Elle, Badulla) - Per passenger	1,250.00	<i>Sri Lanka Railways</i>
16	No. of passenger travel on upcountry railway line per day	1,000	<i>Sri Lanka Railways</i>
17	No. days to clear debris on railway	10	<i>Sri Lanka Railways</i>
18	Railway station replacement cost	20,000,000.00	<i>Sri Lanka Railways</i>
Electricity			
19	Replacement cost of electricity line (LKR) per m	10,000.00	<i>Local authority</i>
Water Supply			
20	Replacement cost of Water Supply line (LKR) per m	3,000.00	<i>Local authority</i>
Drainage line			
21	Replacement cost of drainage line (LKR) per m	7,000.00	<i>Local authority</i>
Costing for commercial activities			
22	No. of days service disturbance	15 days	
23	Disruption to business per day - Bank (LKR)	10,000,000.00	<i>NTB Bank</i>
24	Disruption to business per day - Insurance company (LKR)	8,000,000.00	<i>Sri Lanka Insurance</i>
25	Disruption to business per day - Fuel station (LKR)	5,000,000.00	<i>Ceypetco</i>
26	Disruption to business per day - Tea factory (LKR)	33,333.33	<i>Tea factory - Deniyaya</i>

EXPLANATION ON LIMITATIONS & ASSUMPTIONS

Elements No.	Description
01	Value per human life has been calculated as death compensation provided by the National Insurance Trust Fund. It is valued as LKR 100,000.00 per human life. Further details available at www.nitf.lk/ENGLISH/National%20Natural%20Disaster.html
02	Compensation provided by the National Insurance Trust Fund for property damage (house and SME) is LKR.2.5 Mn. Further details available at www.nitf.lk/ENGLISH/National%20Natural%20Disaster.html Accordingly, value of the building is assumed as LKR.2.5 Mn. It is assumed all buildings locate within project area is same type with unique features.
03	Different type of vehicles are moved on the road. Its fuel efficiency is differed from vehicle to vehicle. Therefore, it is assumed that averagely vehicle fuel efficiency is 10 km per liter.
04	Average fuel rate in Sri Lanka is considered as LKR 150.00 per liter.
05	According to the Road Development Authority (RDA) of Sri Lanka, RDA is designing the roads with 15,000 vehicles carrying capacity per day in one lane.
06	Road Development Authority sources reveals number of vehicles move in C & D class roads (consider 1 lane) is 1,000 vehicles per day
07	Road Development Authority sources reveals number of vehicles move in A class road (consider 2 lanes) is 30,000 vehicles per day
08	Road Development Authority sources reveals number of vehicles move in B class road (consider 2 lanes) is 30,000 vehicles per day
09	Road Development Authority sources reveals it will take 10 days to clear debris on road.
10	Rates provided by local authority reveals cost for debris clearance in the event of landslide incidence is LKR 1200/m ²
11	Road Development Authority sources reveals it will cost LKR15,000.00 per m ² to repair carpet road
12	Road Development Authority sources reveals it will cost LKR 2,000.00 per m ² to repair tar road
13	Rates provided by Sri Lanka Railways for construction of 1-meter railway line is LKR 480,000.00
14	Maximum ticket value of per passenger in Colombo-Kandy railway route is LKR 500.00 Further details available at http://www.gic.gov.lk/gic/index.php?option=com_info&id=432&task=info&lang=en
15	Maximum ticket value of Per passenger in Colombo Nanuoya, Elle, Badulla railway route is LKR 1,250.00 Further details available at http://www.gic.gov.lk/gic/index.php?option=com_info&id=432&task=info&lang=en
16	As per the information provided by Sri Lanka Railways approximately 1000 passengers commute in upcountry railway line per day.
17	Sri Lanka Railways informed it will take at least 10 days to clear debris along rail way line.
18	Sri Lanka Railways sources claimed cost for construction of rail way station is LKR 20,000,000.00
19	Rates provided by local authority to replace electricity line per meter is LKR 10,000.00
20	Rates provided by local authority to replace Water Supply line per meter is LKR 3,000.00
21	Rates provided by local authority to replace drainage line per meter is LKR 7,000.00
22	It is assumed in the event of landslide incident it will disturb service of commercial activities nearly for 15 days
23	It is assumed in the event of disaster, disruption to business in a bank per day is LKR 10,000,000.00
24	It is assumed in the event of disaster, disruption to insurance company per day is LKR 8,000,000.00. Value was obtained from Sri Lanka Insurance Corporation.
25	It is assumed in the event of disaster, disruption to fuel station per day is LKR 5,000,000.00. Value was obtained from Ceypetco.
26	It is assumed in the event of disaster, business disruption in tea factory per day is LKR 33,333.33. Value was obtained from Tea factory - Deniyaya.

BENEFIT ANALYSIS

Critical Sites 1 - 27					
Total no. of Critical Sites - 27					
Description		Unit/Unit Value		Qty	Value (LKR)
Impact to human life					
Human life vulnerability	No. of human lives in risk	value for life (LKR)	100,000.00	1,840	211,000,000.00
Land use Management					
<i>Observed Land use management category</i>					
<i>Previous Land use</i>					
<i>Current Land use</i>					
Impact to the properties					
		Average Cost Per House (LKR)			
Property Damage	No. of vulnerable buildings	2,500,000.00		305	762,500,000.00
If, landslide occurred	Fully Damage Buildings	2,500,000.00		36	0.00
	Partially Damage Buildings	2,500,000.00		15	0.00
Estimation of the economic lose					
Economic Lose	Occurred	Potential			
Component	Unit	Unit cost	Estimated Economic lose		
<i>Damage to the land</i>	Average impact area	Land value per perch (LKR)			2,423,495,400.00
<i>Impact area</i>	Approx. area of project impact (perch)			43,062.08	
<i>Damage to infrastructure</i>	Exposed length of the roads				
<i>Access roads</i>	Cost of debris clearance (LKR)	LKR 1200/m2	m2	41,985.00	50,382,000.00
	Cost for use alternation road (LKR)	distance to bypass	km	662.30	2,617,125,000.00
	Road repair cost	Type	Cost (Rs/m2)		
		Road (carport)	15,000.00	36,825.00	552,375,000.00
		Road (Tar)	2,000.00	5,160.00	10,320,000.00
<i>Infrastructure and Services</i>					
Electricity	Exposed length of the network				
	Replacement cost (LKR)	LKR 10,000/m	m	4,465.00	44,650,000.00
Water Supply	Exposed length of the network				
	Replacement cost (LKR)	LKR 3,000/m	m	2,235.00	6,705,000.00
Drainages	Exposed length of the network				
	Replacement cost (LKR)	LKR 7,000/m	m	1,135.00	7,945,000.00
Railway	Exposed length of the network				
	Replacement cost (LKR)	LKR 480,000/m	m	190.00	91,200,000.00
	Rail passenger income loss saving in the route of Colombo - Nanuoya - Ella - Badulla (LKR)	1000 passengers per day, 10 days interruption, cost of ticket LKR 1,250/passenger			250,000,000.00
Services	Exposed commercial activities				75,500,000.00
	Benefit for commercial activities				300,000,000.00
					240,000,000.00
<i>Nature</i>	Forest area	LKR 1,000,000/ha	ha	1.01	1,011,710.00
Benefit	Estimated Benefit (LKR)	with human life factor			7,644,209,110.00
Benefit	Estimated Benefit (LKR)	without human life factor			7,433,209,110.00

23 Additional Landslide Sites						
Total no. of Additional Sites - 23						
Description		Unit/Unit Value		Qty	Value (LKR)	
Impact to human life						
Human life vulnerability	No. of human lives in risk	value for life (LKR)	100,000.00	2,788	278,800,000.00	
Land use Management						
<i>Observed Land use management category</i>						
<i>Previous Land use</i>						
<i>Current Land use</i>						
Impact to the properties						
		Average Cost Per House (LKR)				
Property Damage	No. of vulnerable buildings	2,500,000.00		567	1,417,500,000.00	
If, landslide occurred	Fully Damage Buildings	2,500,000.00		2	0.00	
	Partially Damage Buildings	2,500,000.00		10	0.00	
Estimation of the economic lose						
Economic Lose	Occurred	Potential				
Component	Unit	Unit cost	Estimated Economic lose			
<i>Damage to the land</i>	Average impact area	Land value per perch (LKR)			906,140,600.00	
	<i>Impact area</i>	Approx. area of project impact (perch)		34,504.06		
<i>Damage to infrastructure</i>	<i>Access roads</i>	Exposed length of the roads				
		Cost of debris clearance (LKR)	LKR 1200/m2	m2	20,030.00	24,036,000.00
		Cost for use alternation road (LKR)	distance to bypass	km	424.20	3,431,850,000.00
		Road repair cost	Type	Cost (Rs/m2)		
		Road (carport)	15,000.00	16,700.00	250,500,000.00	
		Road (Tar)	2,000.00	2,080.00	4,160,000.00	
<i>Infrastructure and Services</i>						
Electricity	Exposed length of the network					
	Replacement cost (LKR)	LKR 10,000/m	m	3,060.00	30,600,000.00	
Water Supply	Exposed length of the network					
	Replacement cost (LKR)	LKR 3,000/m	m	2,350.00	7,050,000.00	
Drainages	Exposed length of the network					
	Replacement cost (LKR)	LKR 7,000/m	m	1,350.00	9,450,000.00	
Railway	Exposed length of the network					
	Replacement cost (LKR)	LKR 480,000/m	m	600.00	288,000,000.00	
	Rail passenger income loss saving in the route of Colombo - Nanuoya - Ella - Badulla (LKR)	1000 passengers per day, 10 days interruption, cost of ticket LKR 1,250/passenger			750,000,000.00	
Services	Exposed commercial activities				0.00	
	Benefit for commercial activities				4,000,000.00	
					0.00	
<i>Nature</i>	Forest area	LKR 1,000,000/ha	ha	0.00	0.00	
Benefit	Estimated Benefit (LKR)	with human life factor			7,402,086,600.00	
Benefit	Estimated Benefit (LKR)	without human life factor			7,123,286,600.00	

Other sites (76 sites)				
Description	Unit	Quantity	Unit Value (Rs.)	Value (Rs.)
Houses protected	Rate / house	1,249	2,500,000.00	3,122,500,000.00
Liberation area by mitigation	Land value / perch	350,194	10,000.00	3,501,941,628.33
Road protected	m ²	13,500	16,200.00	218,700,000.00
Electricity network protected	Meter	900	10,000.00	9,000,000.00
Drainage network	Meter	900	3,000.00	2,700,000.00
Length of water supply network protected	Meter	900	7,000.00	6,300,000.00
Lives saved	Number	4,708	100,000.00	470,820,000.00
Sub Total				7,331,961,628.33

RDA sites (7 sites)				
Description	Unit	Quantity	Unit Value (Rs.)	Value (Rs.)
Road protected	m ²	7,500	16,200.00	121,500,000.00
Houses protected	Rate / house	20	2,500,000.00	50,000,000.00
Liberation area by mitigation	Land value / perch		10,000.00	0.00
Electricity network protected	Meter	7,500	10,000.00	75,000,000.00
Drainage network	Meter	7,500	3,000.00	22,500,000.00
Length of water supply network protected	Meter	7,500	7,000.00	52,500,000.00
Road passengers' lives saved	Number		100,000.00	0.00
Sub Total				321,500,000.00

Railway sites (14 sites)				
Description	Unit	Quantity	Unit Value (Rs.)	Value (Rs.)
Railway line protected	Meter	1490	480,000.00	715,200,000.00
Houses protected	Rate / house	45	2,500,000.00	112,500,000.00
Rail passenger income loss saving (Colombo-Kandy)	Person / Day	10000	500.00	5,000,000.00
Rail passenger income loss saving (Colombo-Nanuoya, Elle, Badulla)	Person / Day	10000	1,250.00	12,500,000.00
Railway station replacement cost saving	Per Station	1	20,000,000.00	20,000,000.00
Sub Total				865,200,000.00

COST-BENEFIT ANALYSIS RESULTS

Cost-benefit analysis (CBA) in its most basic form is a framework for the economic assessment of individual investment projects, under which the present value of future streams of benefits and costs are compared. A favorable CBA result for a landslide mitigation measures can be a strong argument for investment. There are some notable flaws with CBA, in particular that results of the analysis will depend on how one defines and values different benefits and costs and on the level of discount rate used.

The cost-benefit-ratio is determined by dividing the landslide mitigation project costs through the landslide mitigation project benefits. The result is presented as ratio. The result is also stated as benefit-cost-ratio for which the benefits are divided through the costs. In this way of representing the results a project is efficient when the result is above one.

Cost Benefit Analysis:
$$\frac{[\text{Estimated Benefit} - \text{Cost for Landslide Mitigation}] * 100\%}{\text{Cost for Landslide Mitigation}}$$

If, result > 0% Project is financially feasible
 If result = 0% Project is financially neutral
 If result < 0% Project is financially unfeasible

Calculation in LKR

Estimated Benefit (LKR): 23,564,957,338.33

Cost of the Project (LKR): 16,848,000,000.00

$$\begin{aligned} \text{Cost-benefit analysis} &= \frac{[\text{Estimated Benefit (LKR)} - \text{Cost for Landslide Mitigation (LKR)}] * 100\%}{\text{Cost for Landslide Mitigation (LKR)}} \\ &= \frac{[23,564,957,338.33 - 16,848,000,000.00] * 100\%}{16,848,000,000.00} \\ &= 40\% \end{aligned}$$

Calculation in USD

USD conversion rate: LKR 162.00

Estimated Benefit (USD): 145,462,699.62

Cost of the Project (USD): 104,000,000.00

$$\begin{aligned} \text{Cost-benefit analysis} &= \frac{[\text{Estimated Benefit (USD)} - \text{Cost for Landslide Mitigation (USD)}] * 100\%}{\text{Cost for Landslide Mitigation (USD)}} \\ &= \frac{[145,462,699.62 - 104,000,000.00] * 100\%}{104,000,000.00} \\ &= 40\% \end{aligned}$$

ANNEXES

COST-BENEFIT ANALYSIS - 27 CRITICAL SITES IN BRIEF

Site no.	Value of Benefits (LKR)	Mitigation Cost (LKR)	Cost Benefit Analysis
Site 01	34,107,000.00	70,000,000.00	-51%
Site 02	828,076,000.00	86,500,000.00	857%
Site 03	117,447,800.00	107,000,000.00	10%
Site 04	61,360,000.00	75,000,000.00	-18%
Site 05	46,365,000.00	90,000,000.00	-48%
Site 06	286,870,000.00	40,000,000.00	617%
Site 07	147,700,000.00	9,000,000.00	1541%
Site 08	36,269,700.00	60,000,000.00	-40%
Site 09	159,398,200.00	75,000,000.00	113%
Site 10	302,860,000.00	75,000,000.00	304%
Site 11	720,742,000.00	437,500,000.00	65%
Site 12	297,150,000.00	55,000,000.00	440%
Site 13	734,652,800.00	105,000,000.00	600%
Site 14	40,401,100.00	9,000,000.00	349%
Site 15	327,481,210.00	83,000,000.00	295%
Site 16	228,577,600.00	35,000,000.00	553%
Site 17	262,036,300.00	160,000,000.00	64%
Site 18	328,826,000.00	82,000,000.00	301%
Site 19	49,448,900.00	50,000,000.00	-1%
Site 20	930,970,000.00	85,000,000.00	995%
Site 21	83,592,000.00	60,000,000.00	39%
Site 22	323,222,500.00	100,000,000.00	223%
Site 23	296,961,000.00	84,000,000.00	254%
Site 24	257,077,100.00	115,000,000.00	124%
Site 25	167,325,000.00	80,000,000.00	109%
Site 26	374,664,800.00	13,000,000.00	2782%
Site 27	200,627,100.00	19,000,000.00	956%

COST-BENEFIT ANALYSIS - 23 ADDITIONAL SITES IN BRIEF

Site no.	Value of Benefits (LKR)	Mitigation Cost (LKR)	Cost Benefit Analysis
Site 029	80,856,000.00	69,600,000.00	16%
Site 030	232,928,000.00	91,000,000.00	156%
Site 037	14,250,000.00	53,500,000.00	-73%
Site 042	463,500,000.00	80,300,000.00	477%
Site 052	599,520,000.00	85,600,000.00	600%
Site 060	333,400,000.00	64,200,000.00	419%
Site 061	220,924,600.00	91,000,000.00	143%
Site 063	99,550,000.00	80,000,000.00	24%
Site 068	88,264,000.00	58,900,000.00	50%
Site 069	549,434,000.00	96,300,000.00	471%
Site 084	119,790,000.00	53,500,000.00	124%
Site 087	67,360,000.00	53,500,000.00	26%
Site 088	142,560,000.00	37,500,000.00	280%
Site 091	90,330,000.00	60,000,000.00	51%
Site 120	1,161,400,000.00	58,900,000.00	1872%
Site 125	356,800,000.00	85,600,000.00	317%
Site 127	402,900,000.00	42,800,000.00	841%
Site 128	486,035,000.00	48,200,000.00	908%
Site 129	190,620,000.00	48,200,000.00	295%
Site 137	170,380,000.00	53,500,000.00	218%
Site 139	640,600,000.00	42,800,000.00	1397%
Site 145	680,060,000.00	85,600,000.00	694%
Site 147	210,625,000.00	63,100,000.00	234%