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Review

Undertaking loss reduction measures to prevent slope failures

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Landslides or slope failure has slowly become a major concern in Malaysia due to the rapid development of rural areas. Despite advances in science and technology, these events continue to result in human suffering, millions in property losses and environment degradation. It is a fact that with continuous population increase the economic development becomes more complex, while the economic and societal costs of landslides will continue to rise. Hence there is a need for a comprehensive program to reduce landslide losses that will marshal the capability of all levels of government and private sector. Successful and cost effective landslide loss reduction measures can and should be taken in the many jurisdictions facing landslide problems. Federal and state governments can prevent and reduce landslide losses through, creation of early warning and monitoring system, better policy and effective implementation, outlining design procedures, creation of local hazard mapping, land use management, building, grading controls, among others. Hence this paper addresses some of the measures proposed as part of loss reduction measures in order to minimize potential landslides or slope failures.

Key words: Loss reduction, slope failure, landslide, stability, development planning, slope management, early warning.

INTRODUCTION

The objective of loss reduction measures is to develop appropriate mitigation measures in order to eliminate or minimize losses to life, properties and economic due to landslide (Robert, 2000; William, 2000). In order to meet the objective, it was proposed that a framework of guidelines on planning, design, construction and maintenance of slopes to reduce risk from landslides be developed. In order to derive a feasible legal framework as part of new guideline under loss reduction measures, the process flow of land development such as planning, application, approval, design, construction and maintenances need to be identified and fine tuned to enforce loss reduction measures. Hence loss reduction measures need to be taken into consideration at every stage of development such as;

i. Loss reduction measures within the current legal frame work.
ii. Loss reduction measures during development planning stage.
iii. Loss reduction measures during design stage.
iv. Loss reduction measures during construction stage.
v. Loss reduction measures by enhancing maintenance, management and monitoring of slopes.

LOSS REDUCTION MEASURES WITHIN THE CURRENT LEGAL FRAME WORK

There are several laws, policy and institutional frameworks

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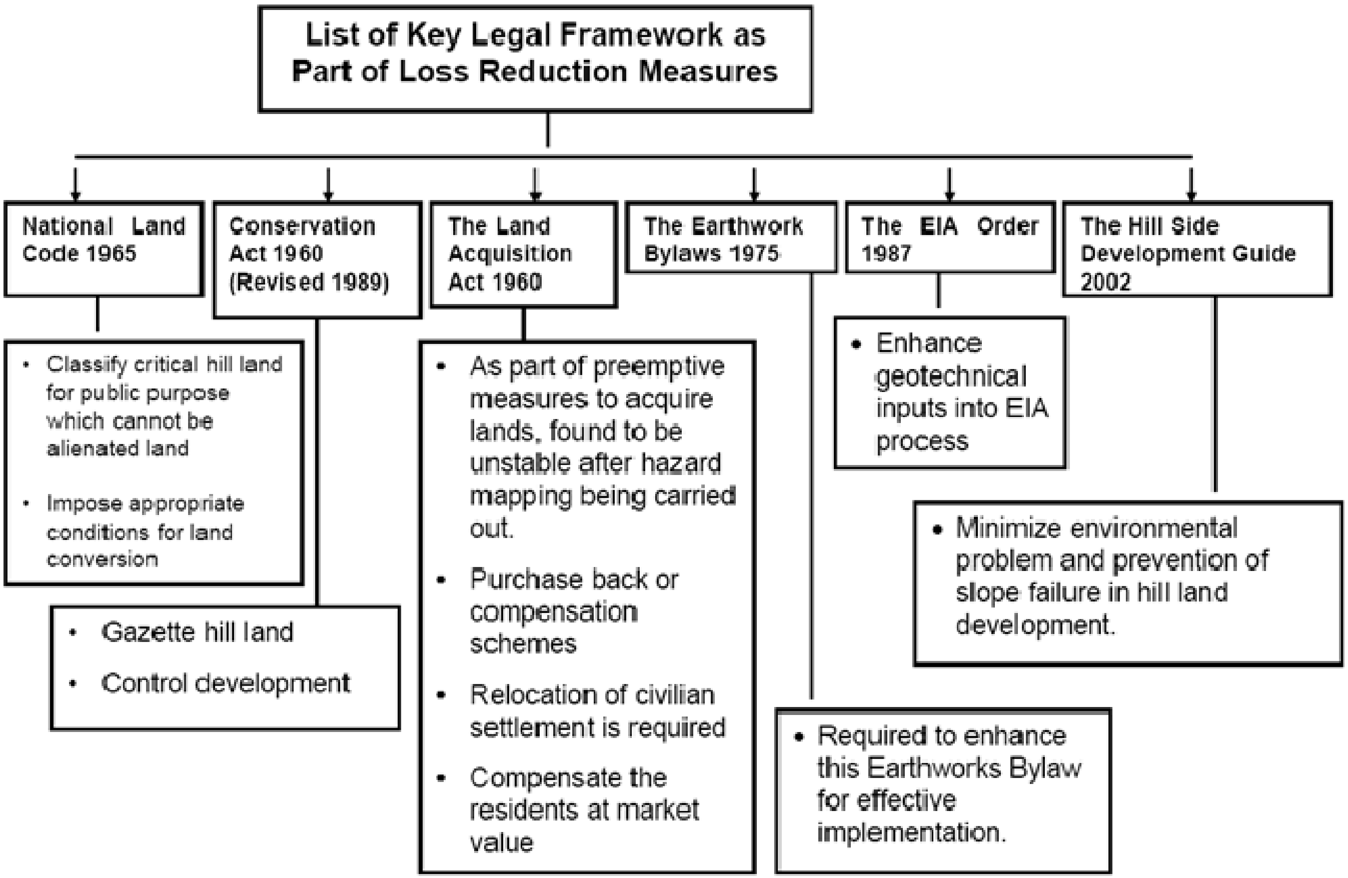

Figure 1. List of key legal framework as part of loss reduction measures.

developed for landslide risk reduction, mitigation and disaster preparedness which contain provisions for the protection of hill land development. A list of relevant laws and guidelines that may be applicable to the management of land in relation to slope failures which has some level of loss reduction measures are as listed below. Figure 1 shows list of key legal framework as part of loss reduction measures.

National land code 1965

The code contains provisions for dealing with hill land. As land is the property of the state, the authority has the right to reserve land for any public purpose by notification in the Gazette. As such, the state government can set aside hill land as “reserved land”, “catchment land” or “forest reserves” and thereby protect such land from being developed.

Conservation act 1960 (Revised 1989)

The conservation act gazettes hilly land as “hill land”. Hilly land is not specifically defined but to all intents and purposes, it is interpreted to mean hill areas with steep slopes. The act has many sections which provide for the protection of hill land from development, especially in relation to soil erosion. Under the act, any land within the state may be declared as hill land by the Ruler in Council of a state by notification in the Gazette. As such, it is entirely up to the state to decide on what constitutes hill land and what does not. Hence it is proposed for the states to carry out hazard mapping to identify those hazardous areas and gazette them if required.

The land acquisition act 1960

This act provides for the acquisition of hill land whenever it appears desirable to the Ruler in Council to acquire any hill land for the purpose of preventing loss of life due to slope failure. This act should also be considered as part of preemptive measures to acquire lands which are found to be unstable, after hazard mapping has being carried out. Purchase back or compensation schemes to the land owner can be introduced to pay for the lost of land for potential development. If relocation of civilian settlement is required, the state government should undertake the task to compensate the residents at market value (Ngai, 1998).

The earthwork bylaws 1975

There are too many irregularities in the earthwork bylaw in Malaysia which is not effective in ensuring that developers abide by the law. Hence some measures are required to enhance this earthworks bylaw regulation for effective enforcement.

The environmental impact assessment (EIA) order 1987

This order stipulates that it is mandatory to submit an EIA for projects covering 50 ha or more. Many developers go round this law by submitting proposals for projects just under 50 ha. However, it is entirely up to the Department of Environment (DOE) to impose the EIA ruling even for projects less than 50 ha at environmentally sensitive areas such as hill lands.

The hill side development guide 2002

Considering the risk factors involved in slope design a new guide line for hill land development was circulated by "State Chief Secretary" on 21st March, 2002, with instruction given to all state government on procedures that should be followed to minimize environmental problem and prevention of slope failure in hill land development.

LOSS REDUCTION MEASURE DURING DEVELOPMENT PLANNING STAGES

At this stage when a development requires heavy earthwork, example exceeding 50,000 m^3 of cutting and filling works, measures or steps to reduce losses in the even of slope failure need to be incorporated. Such loss reduction measures should also consider losses due to;

a. Possible loss of life during construction and post construction period.
b. Direct structural damage to building and neighboring development.
c. Damage to essential facilities such as:
i. Electricity and communication transmission line.
ii. Transportation and utility system.
d. Property losses;
i. Damage of vehicle.
ii. Loss of agricultural and crop.
e. Direct and indirect economical losses.
i. Building repair and replacement cost.
ii. Relocation and restoration expenses.
iii. Wage losses.
iv. Building inventory losses.

Considering the factors above, detailed evaluation needs to be considered in terms of development plan, land use, engineered slope stabilization work and adequacy of factor of safety derived. The current development guidelines need to incorporate loss reducing measure by dictating the following;

i. Maximum cut; fill height and natural slope angle allowed in the proposed development lot.
ii. Minimum factor of safety required for stability by considering the potential losses which could incur.
iii. Verification of design practice adopted.
iv. Need for geological evaluation of the natural terrain to identify adverse geological condition and natural ground water flow.

The current guideline from hill land development is based on slope angle classification which should also consider slopes beyond lot boundary before approving the development order. Example, in some cases the hill slope toe angle is less than 25° within development lot boundary. However, rapid increment in slope angle is observed beyond the proposed development lot boundary. Hence before a development order is issued, overall terrain mapping needs to be furnished by the developer together with slope angle and hazard classification for authority evaluation. The evaluation exercise should consider the following:

i. The hill land slope angle within lot boundary and beyond.
ii. Restrict cutting of slope within development lot which will progressively undermine the stability of slope at adjacent lot.
iii. Study the groundwater flow tread to identify natural artesian or under ground sub terrain flow.
iv. The propose engineering solutions for cut and fill slopes, are required to be forwarded for evaluation by the authorities before issuing any development order.
v. Recommend the usage of adequate subsoil drainage system in order to eliminate water pressure build up on cut slope and the lost of fines on fill slopes which will progressively undermine the overall slope stability.
vi. Consider the social economic and lost of life factor due to any slope failure caused by the proposed development.
vii. Include environment protection consideration by adopting erosion and sediment control guideline.

The creation of durable and effective solutions for a development planning approval guideline for slopes will require a continuing dialogue among practicing engineers and authorities involved directly or indirectly in order to fine tune the steps required to be taken to reduce losses due to slope failure. An effective development planning legal framework will require a combination of engineering

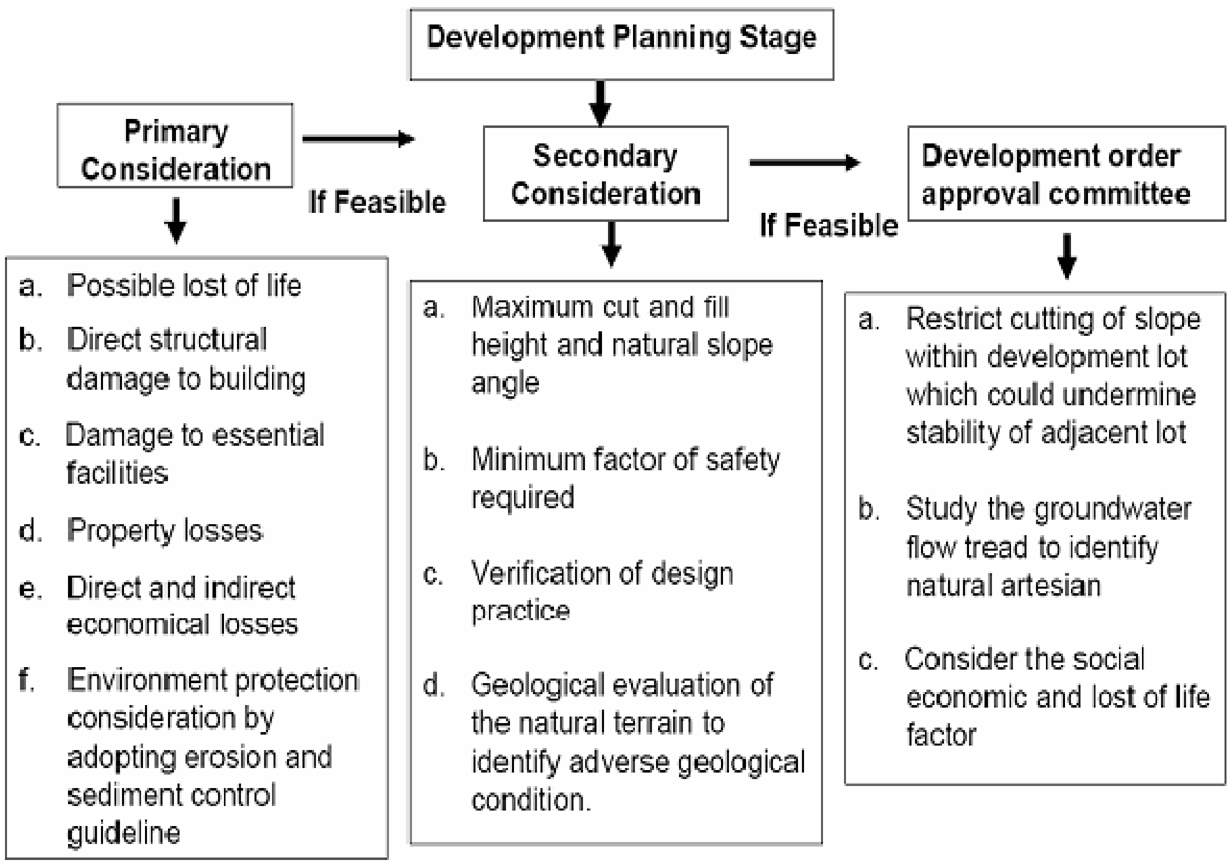

Figure 2. Some loss reduction factors to be considered during development planning stage.

and management solution to ensure coordination and consortium-type decision making to accommodate the multi-jurisdictional, cooperative nature of approval committee. The established working committee should be represented by federal and state governments, academia and private practitioner to review critical development plan. Figure 2 shows some loss reduction factors to be considered during development planning stage.

LOSS REDUCTION MEASURE DURING DESIGN STAGES

For development projects, during the design stage, the officers of the local authority and the pertinent technical departments monitor the implementation of the development projects to ensure that they are carried out according to the approved plans or design. The project proponent's consultants have to comply with various requirements under the Uniform Building Bylaws and the Earthworks Bylaws. The authorities have the powers to stop any work that does not comply with planning and building approval conditions. To effectively reduce losses during the design stages various steps need to be taken into consideration in Malaysia especially on;

Research on slope engineering

This helps to perform hazards and risk management or mapping to in order to evaluate how the impacts of a single or multiple hazards can be reduced, by undertaking detail study of the project site. The fundamental view to incorporate risk and loss analysis is to consider all risk factors faced by a populated area in term of slope failures and to develop a risk management strategy accordingly. These sources of problems can range from comment occurrences for minor slope failure to rare, major disasters. Hence, establishment of a systematic research approach in order to develop standards or guideline for Malaysian engineering society to follow is crucial.

Toward total risk and loss management framework

The ‘‘bottom line’’ of slope hazards and risk management is often expressed in terms of reduction of death and injuries and/or reduction of the monetary losses associated with slope failures. The principle is not to minimize risk but rather to maximize the public net benefit. Thus, benefit-cost analysis should be an integral part of risk analysis. Risk, cost and reliability are fundamental to engineering analysis. Engineers are required to combine scientific knowledge and associated theory to estimate the workability of design, with professional experience. Engineering planning, design, construction and operating policies are based on formal codification of this scientific knowledge and experience into accepted practice. Until recently, engineers relied on safety factors to account for the uncertainty in estimating how the system would perform. Reliability engineering deals with ''failures'' of any type, whereas the recent interest in risk and cost analysis has been prompted by failures that cause public problems.

Improvement on standards and code of practice

Improvements in code of practice and standards are needed in the engineering aspects of landslide. Some of the steps that can be taken are;

a. Provide funding to attract academic researchers and other professionals to conduct research on landslide prevention measures. (Ali and Osman, 2008; Normaniza et al., 2008)
b. Examine social economic issues relative to landslide prevention, acceptance and enforcement.
c. Redefine land use standards to give more attention to factors causing landslide to create safer living standards.
d. Implement a nationally recognized and voluntary standard.
e. Improve development performance provisions including national and state uniformity combined with improved and easier methods for slope property definition and design.
f. Improve analysis and design procedures for slope design works to ensure quality to the national performance requirements.
g. Develop more effective ways to integrate the scientific input from physical sciences, social sciences and engineering aspects, together with the views from other stakeholders in the process of setting land use and landslide prevention standards.
h. Implement stringent site investigation works together with quality and reliable laboratory works in order to obtain reliable test results.

Integrating loss reduction measures as part of slope analysis

In order to minimize losses associated with slope failures, it is best to integrate loss reduction measures as part of slope analysis. Hence it is recommended to research and develop some of the following hazards mitigation measures;

a. Develop effective and economical methods that can be implemented in the field to evaluate and retrofit existing hazardous settlement or infrastructure subject to natural and man-made landslide.
b. Develop technologies to diagnose and assess the condition and components for slope under pre and post failure situation.
c. Develop outage engineering management technologies to lessen loss of life, facility downtime and to develop rapid rehabilitation and construction methods.
d. Establish the knowledge needed to set system performance standards, evaluation procedures, codes and criteria under natural and man made landslide hazard conditions for major lifeline systems including public and private utilities.
e. Develop high-tech systems to facilitate infrastructure maintenance and operations, such as emergency, damage control, quick recovery and service restoration following a landslide.

During design stages, engineers are required to identify the possible factors causing landslides and its impact on society and economy in order to minimize losses. In terms of the risk of life and economic losses as a consequence of slope failure, the major factor to be considered in any slope study and mitigation measures is the proximity of the slope or earth retaining structure to populated areas, traffic and building as shown in Figure 3. Considering the risk factors involved, slope classification was proposed under the new circulation by chief sectary on 21st March, 2002 and is tabulated in Table 1. A range of triggering and contributory factory leading to the event of a landslide can be classified as shown in Table 2 (Wong et al., 2004).

Incorporation of rainfall intensity as primary part of early warning system in design stage

Rainfall intensity is one of the main factors contributing to landslides in Malaysia with average annual rainfall of about 2000 - 2500 mm. Rainfall induced slope failures are common in Malaysia. Hence providing early warning system based on rainfall intensity and duration can be introduced in the design stage as loss reduction measures. Based on the works of Brand et al. (1984) and Kay (1998), most of the slope failures in Hong Kong occurred within 4 h after peak hourly rainfall and less than 10% of landslides occurred 16 h after the peak hourly rainfall. As a preliminary guide, landslide warning could be issued if 24 h rainfall was expected to exceed 175 mm or 60 min rainfall was expected to exceed 70 mm. The probability of having severe landslide is about 15% (Kwong et al., 2004). Table 3 shows a guide on rainfall intensity and apparent condition of slope. Hence conduct design analysis and perform monitoring works is carried out using DID Department of Irrigation and Drainage hydrology network data. Figure 4 shows some loss reduction factors to be considered during design stage (Wong et al., 2004).

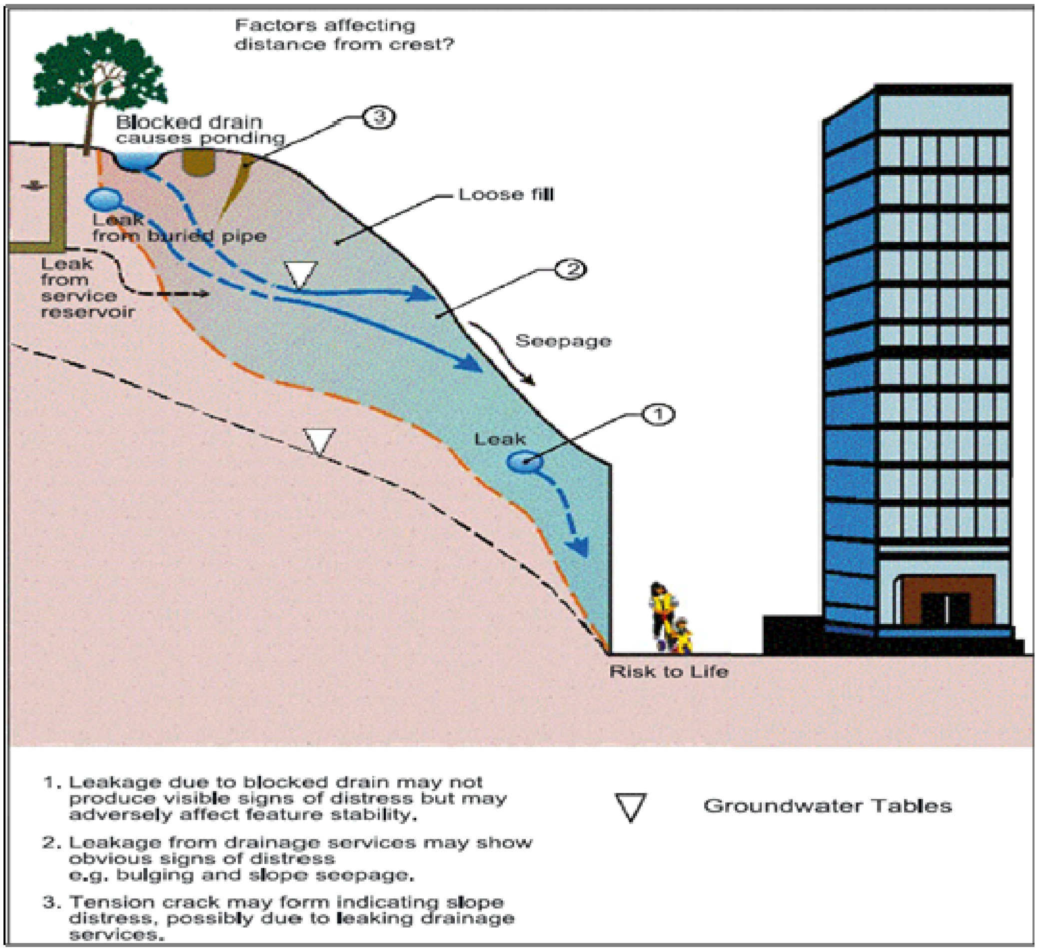

Figure 3. Contribution of poor maintenance for slope instability (Wong et al., 2004).

Table 1. Guideline for physical development as per hill side development guide 2002.

Class	Guidelines
I and II	Development is allowed for hill 1 and with slope angle less than 25°. Complied to "Garis Pembangunan Di Kawasan Bukit 1997 Jawatankuasa Kerja Tanah (JKT) and Garis Panduan Kawalan Hakissan dan Kelodakan", 1996 Jabatan Alam Sekitar (JAS).
III	Development is allowed for hill 1 with slope angle ranging between 26-35°. However, environmental impact assessment (EIA) report must be prepared. Scope of EIA Follow the requirement under the "Handbook of EIA Guidelines 2001". Geology and geotechnical report required to be prepared. Summit erosion risk map. Propose procedure to maintain slope stability and erosion control measures. Detail EIA procedure and report is required for development area which has a slope angle 26 - 35° and cover 50% or more of development area.
IV	Development is not allowed on hill land with slope angle exceeding 35°.
General Items	For development site which has class I, II, III and IV, development is restricted only to areas of class I, II and III.

Table 2. Summary of landslide triggering and contributory factor (Wong et al., 2004).

S/no	Landslide triggering factors
	Rainfall intensity and rise in ground water level among others
1	Adverse construction/ human activities
2	Deterioration and erosion of surface
3	Bursting and leakage of buried water services
4	River erosion and flooding contributory factors
5	Adverse geological conditions
6	Substandard and inadequate site investigation works
7	Inadequate design practice
8	Poor construction work
9	Adverse topography condition
10	Inadequate maintenance work

Table 3. Summary of landslide triggering and contributory factor (Wong et al., 2004).

Rainfall intensity centre	Apparent conditions of slope
≥ 25 mm/day	Show signs of surface erosion
≥ 50 mm/day	Surface erosion intensify
≥ 100 mm/day	Stability deteriorate, marginally stable slope may deform and move
≥ 150 mm/day	Marginally stable slope may deform or collapse
≥ 200mm/day	Marginally stable slope may deform or collapse
	Stable slope may show signs of instability
≥ 250 mm/day	Stable and well vegetated slope may also deform or collapse

LOSS REDUCTION MEASURES DURING CONSTRUCTION

Quality construction management is an important factor for development at hill site. Guidelines should be followed during supervision of hill site development especially on the formation of cut and fill slopes. The supervising individual should have sufficient knowledge and experience in geotechnical engineering to identify irregularities of the subsurface condition such as soil type, surface drainage, ground water level, weak plane such as soft clay, geological formation and boundaries, soil weathering profile, bedrock or rock outcrop profile among others that might be different from that envisaged and adopted in the design. If required, perform additional site investigation work to verify the subsoil profile, especially at areas of soft clay and lime stone bedrock should be carried out.

Project managers and site staff are required to keep detailed records of the work progress and the site conditions encounter when carrying out the works and in particular when irregularities like clay seams and significant seepage of groundwater are observed. Quality record keeping must be carried out on modifications to the initial design to suit site conditions. Quality control exercise should include, record keeping of manufacture's quality control records, field laboratory load testing records to validate design loads and other tests carried out. Sufficient photographs of the site before, during and after construction should be taken and archived. These photographs should be supplemented by information like date, weather conditions and irregularities of the subsoil conditions observed during excavation.

During slope cutting or embankment filling works, it is important to provide sufficient drainage system for both temporary and permanent conditions. Provide sufficient temporary protection works to avoid failures during construction works. In the event of cut or fill slope stabilization required, sufficient and quality stabilization solutions should be provided. As for embankment filling, it is required to be done according to stringent compaction specifications with regular density inspection. The surface of slope both cut and fill are required to be protected against erosion and gully formation using surface reinforcement or turfing or hydro seeding.

As for the environmental protection, it is important to prepare sufficient silt traps, wash troughs and provide sufficient drainage system to prevent any damage to the environment such as rivers and lakes, which could cause water pounding and flush floods. The construction activities are required to follow guideline on environmental protection during construction works both in cooperate and adopt regulation during construction work. Figure 5 shows some loss reduction factors to be considered

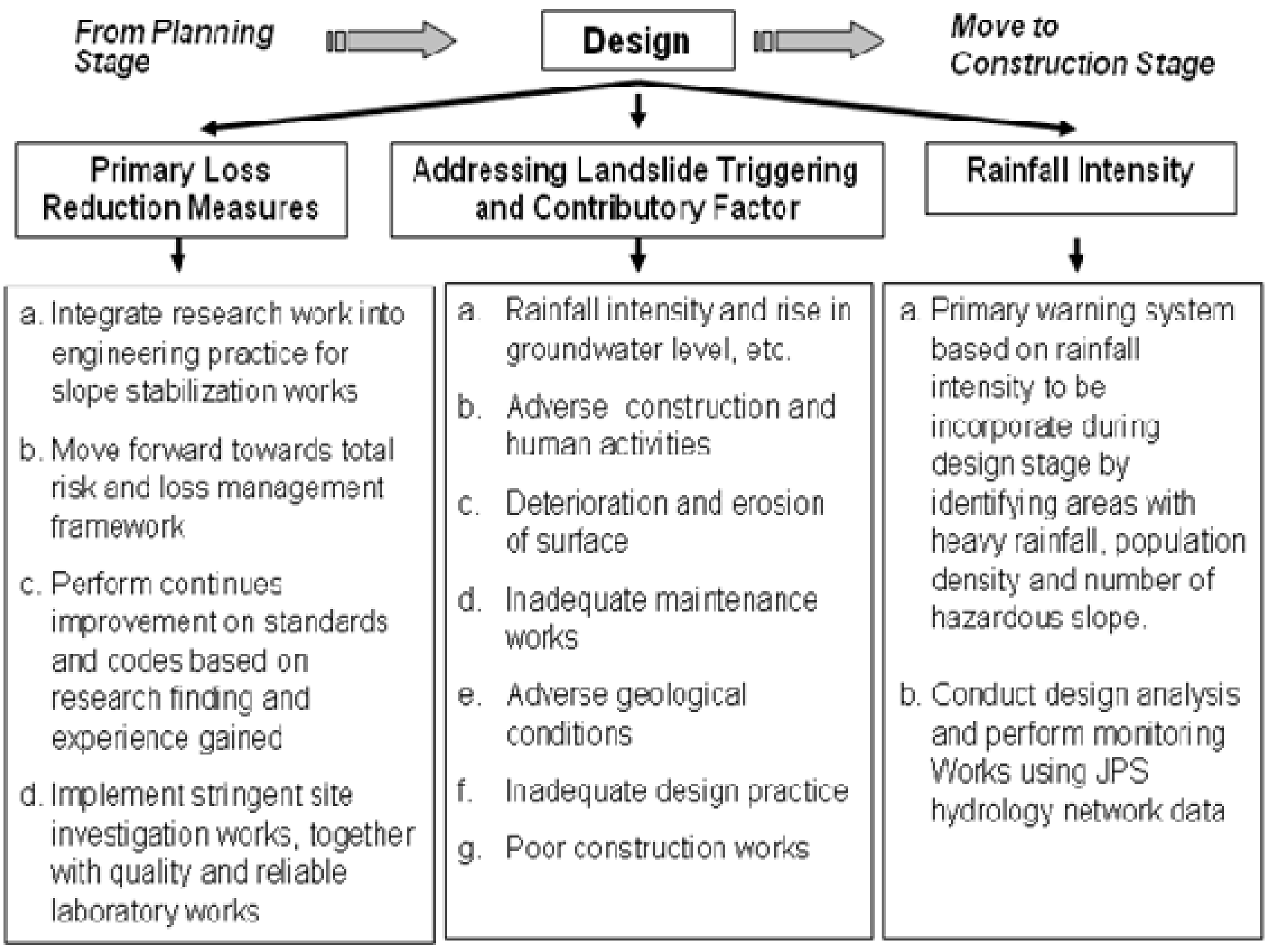

Figure 4. Some loss reduction factors to be considered during design stage.

dered during construction stage.

LOSS REDUCTION MEASURES BY ENHANCING MAINTENANCE, MANAGEMENT AND MONITORING OF SLOPE

The use of monitoring and observational approach needs to be adopted as part of maintenance works on critical slopes (Maceo-Giovanni et al., 2000). Data collected under monitoring and observation could be used for back analysis of engineering parameters and failure mechanisms development (Ali, 1993). The cost for these works should be incorporated as part of annual commitment by state government to reduce the likelihood of slope failure. A working office need to be established to undertake the task to perform engineering audit and issuing of certificate of compliances for critically hazards slope in the aspect of mitigation, prevention, monitoring of landslide and rock fall with allocation of emergency respond and recovery fund. Some of the steps that need to be taken as part of loss reduction measures are;

i. Registration of slope details in order to prioritize the mitigation measures base on the data obtained from early warning system.
ii. Provision of a slope information system to the public, to create public awareness of the potentially hazardous slope and be responsible for the slope maintenance and repair works within and beyond the lot boundary.
iii. Establishment of consultancy contract so that wider professional resources can be gathered to mitigate the slopes in a shorter period of time.
iv. Establishment of external review board to create channel for technical exchange of latest development of technology and research.
v. Establishment of landslide warning system for early notification of potential hazards to the public so that people can stay away from slopes during heavy rainfall.
vi. Establishment of emergency team of professional staffs who can arrive at landslide location at the earliest possible time to provide advice for restoration or temporary stabilization repair works and gather first-hand geological information for detailed engineering failure studies.

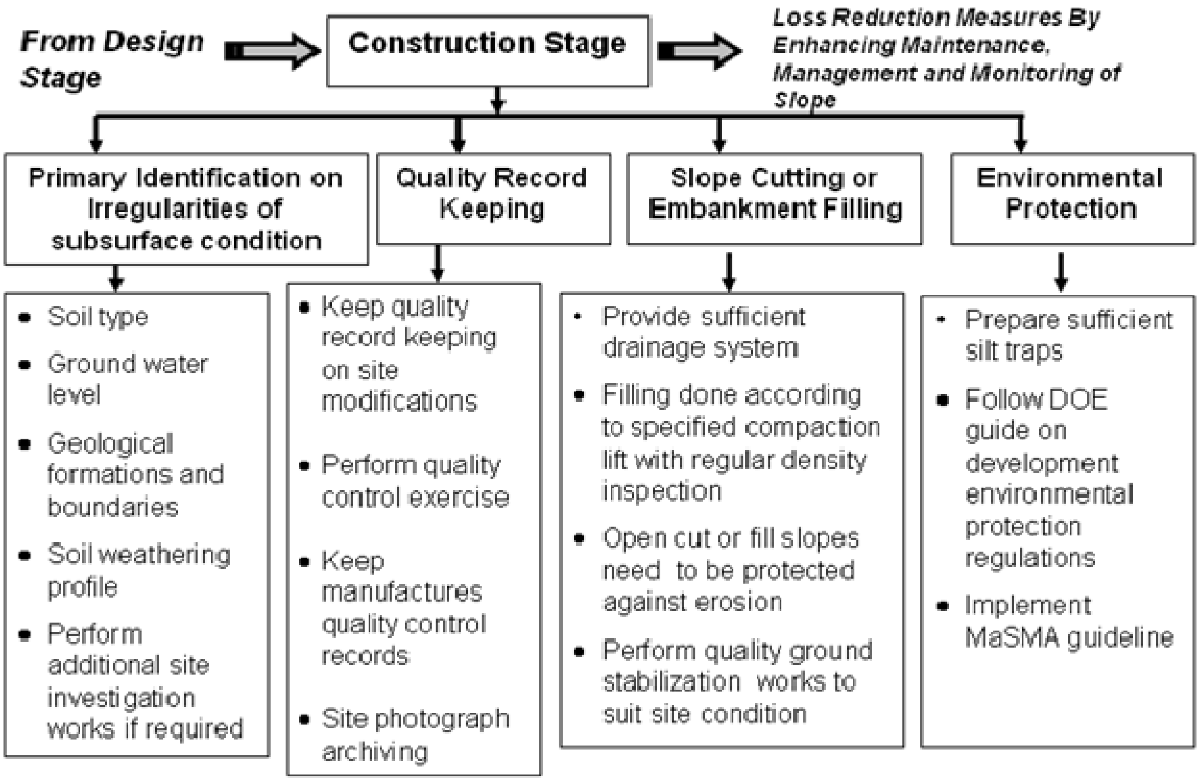

Figure 5. Some loss reduction factors to be considered during construction stage.

vii. Identification of maintenance team for slopes and enforcement of regular inspection, review and maintenance of slopes.
viii. Provision of education to the public regarding proper registration, maintenance of slopes and reporting of landslides.

Figure 6 shows some loss reduction factors to be considered during maintenance stage.

USE OF TECHNOLOGY FOR LANDSLIDE MITIGATION

The development in information technology could play a major role in providing or integrating the state of art technology needed to manage, analyse, predict and respond to potential landslide event in order to minimize the losses (David, 1992; Keiko and Satoru, 2006).

Hence there is a great necessity to integrate information currently available from various agency to create a centralize slope database. The key elements of the proposed slope database are;

i. Management of slope.
ii. Landslide risk analysis.
iii. Potential landslide prediction.
iv. Response to landslide event.

Figure 7 shows the slope database integration as advance landslide mitigation technology and a major effort for loss reduction.

At present, the communication and information exchange between government organizations, universities and private bodies have not been established to create a national slope or landslide database. Hence it is important to develop a centralize landslide mitigation technology which is accessible to various government, universities and selected private organization to update, review, analysis and predict potential landslide and create early warning system and respond accordingly. It is also proposed to use the advancement in information technology and the “e-government” policy of Malaysia to rapidly increase the number of information system and types of spatial data available. By integrating the spatial information on areas at risk of landslide disasters using web based Geographical Information System (web GIS) with interactive smart maps, database and also incooperating precipitation data, the ability to predict landslides can be enhanced.

Conclusion

This paper addresses some of the measures proposed as part of loss reduction measures by enhancing legal, planning, design, construction and maintenance framework

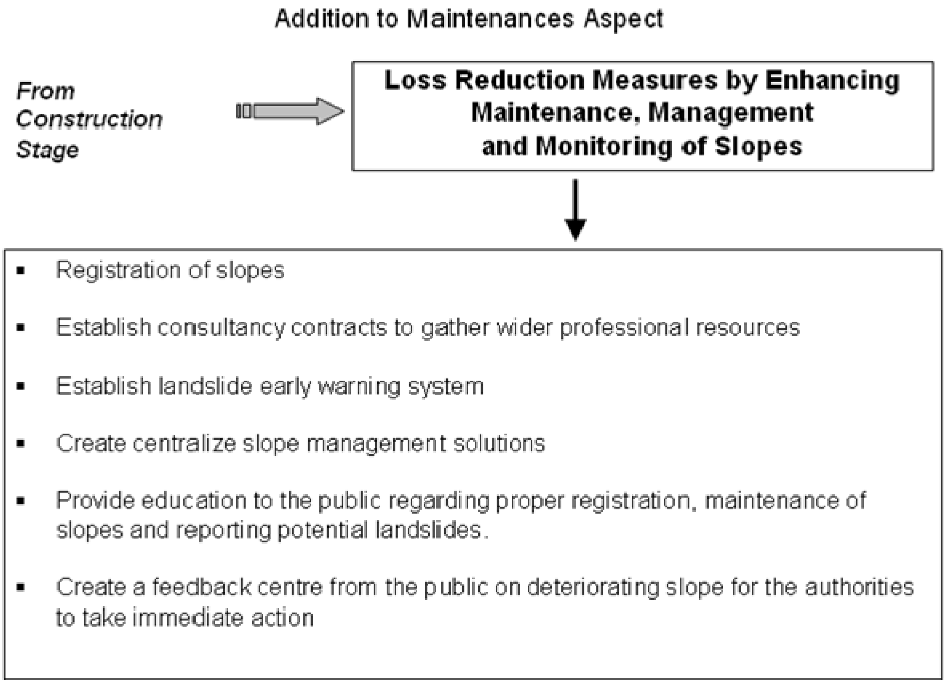

Figure 6. Some loss reduction factors to be considered during maintenance stage.

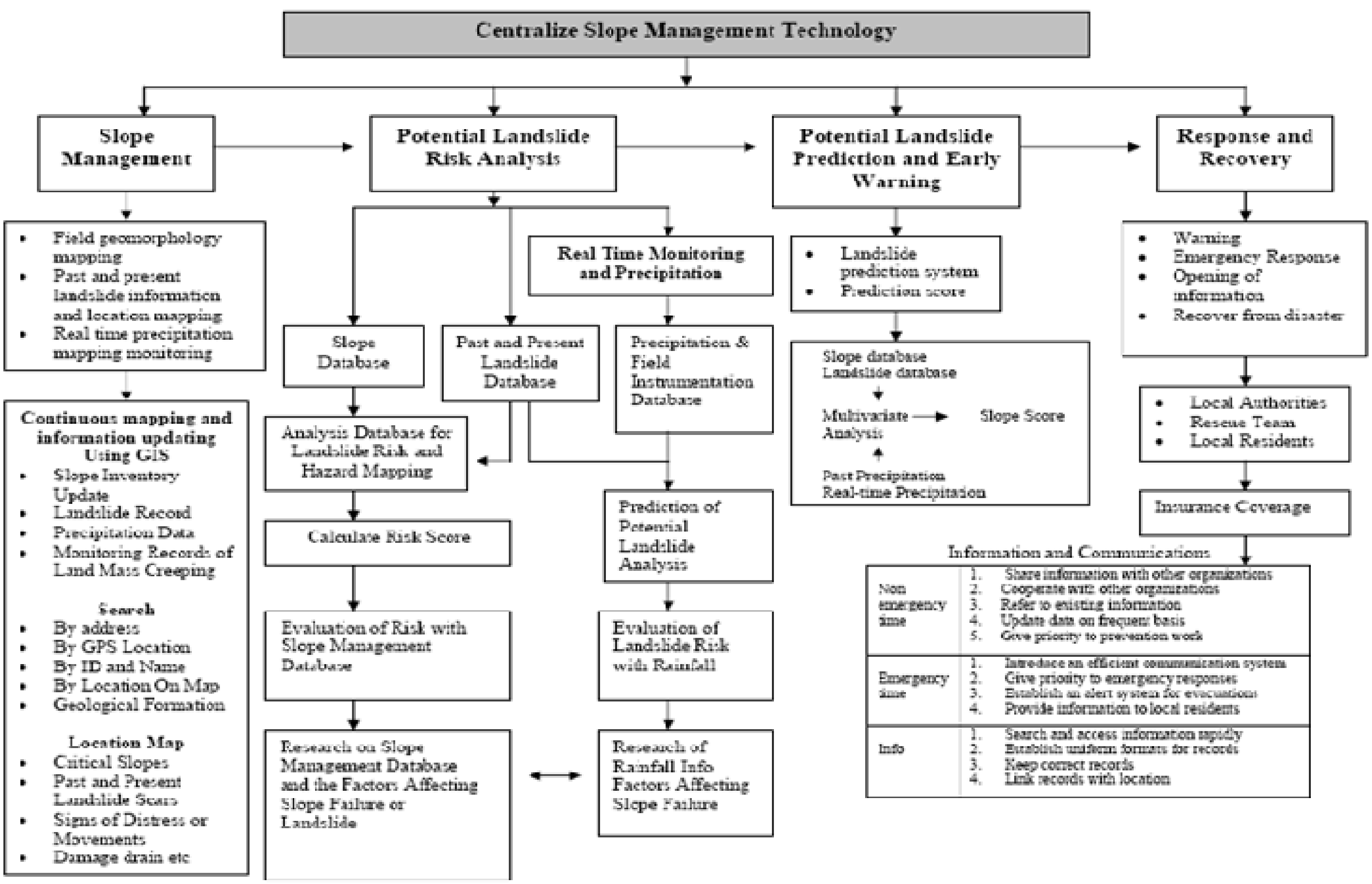

Figure 7. Shows the slope database integration as advance landslide mitigation technology and a major effort for loss reduction

to prevent slope failure or landslide.

It is clear from the flow process as presented, that for the application of a standard development policy, particularly those that involve hill site or sloping terrains, potential shortcomings/ impediments could arise from the relevant vetting procedures within or by named agencies or departments responsible for such tasks, on the aspects of planning approval, design acceptance, construction and maintenance.

Successful and cost effective landslide loss reduction measures can and should be taken in the many jurisdictions facing landslide problems. State and local governments can prevent and reduce landslide losses through, creation of early warning and monitoring system, better policy and effective implementation, outlining design procedures, creation of local hazard mapping, land use management, building, grading controls, among others.

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