An Assessment of Predominant Errors Posing Vulnerability to Malaysian Landslides

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***Abstract*—The numbers of landslides in Malaysia are escalating day by day, putting blames on triggering factors such as rainfall or any other natural calamities. In totality, this is indeed a misperception. Large percentage of slope failures are sparked by flaws / errors originated from either behavior or managerial and technical issues. Errors may be implicit, committed during planning, design, construction, installation and fabrication, as well as operation and maintenance leading to slope failure subsequently. In this particular region of Malaysia due to torrential rainfalls, the other provocative and instigating factors are often overlooked resulting in greater number landslides gradually. In this study author has compiled a list of design construction and maintenance error sources, these sources are then evaluated according to its proportion through expert's opinions and directly related personnel. Following the analysis and deliberations, the author has propounded a combined framework to minimize the influence of errors pertinent to various activities. The error sources have been matched with already in hand error producing conditions present in one of the error analysis technique known as Human Error Assessment and Reduction Technique (HEART).**

***Index Terms*—error producing conditions, assessed proportion of affect, performance shaping factors**

I. Introduction

Among other natural calamities, landslides are also part of various natural catastrophes. The end result of landslides results in far reaching consequences that includes grievous economic and social losses. Landslides along with associated slope instability have become increasingly more common in many parts of the world and are liable for substantial losses in the sense of both compensatory and non-compensatory. Specifically, with reference to Malaysia; the landslide problems is aggravating as a result of rapid economic development especially on hilly terrain after 20 years. National slope master plan 2009-2023 imitates the cases of massive landslides. Triggering factor is mainly rainfall as Malaysia is facing two monsoon seasons every year. Its average rainfall is 2550mm per year which is exceeding the worldwide average. Mostly blaming factor or common stimulators of landslides is the intense rainfall and send-off aside other causal factors are the main snag of current state of practice. Tragedy of Bukit Antarbangsa 2008 is the prominent example of this context. It's also deduced from the literature that in many cases of slope failures non maintenance or poor maintenance of drainage system is always unrelenting along with other design /construction deficiencies [1]-[3]. Safety factor approach used in designing of slopes is insufficient as it is not the only criteria to distinguish about the stability of the slopes [4], [5]. Reliability index/probability of failure of the focused case histories prominently shows that adopted design approach is not only insufficient but also not properly grasped [6]. In this study author has pinpointed those conditions due to which these fatal landslides are greatly perpetuating. The governing error producing conditions or sources has been compiled by observing the prominent case studies of Malaysian landslides. In the end a theoretical/ technical framework is produced to counter these flaws.

As compared to other branches of engineering, the branch of slope engineering encounters greater and indeed quite different type of uncertainties. Unseen or hidden geological changes in the earth environment, soil complexity, hypothesis in the geotechnical models and above all flawed design practices, out of order construction and no follow up during operations jeopardizes the system [7]. The issue of uncertainties is not new; it was already bring in, in the starting of seventies. As [8] after profound emphasizes on correct decision making in engineering design, it is paramount to consider these uncertainties that plays a very essential role apart from the state of comprehensiveness and quality of information embedded in the system. Decisions or steps taken by the engineers must be considered keeping in view the expected risk or uncertainties. Basically, landslide is rock or debris movement or slope earth down [9]. Problems of landslides often occur, due to instability of slopes, distressed slopes, cut slopes. [10] Identified that on an average hundreds of landslides are reported every year in Hong Kong due to old slope failures. Cut slopes are usually 40 to 70 degrees and fill carries 30 to 35 degrees. These are manmade (cut and fill) slopes formed at the time, when no geotechnical control existed. It means in any case slope engineering design and construction practices has to be revised or reviewed as it helps in reducing the risks of land sliding.

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A. *Cradles of Error*

To overcome or minimize future accidents, there is an immense need now to work on those factors mainly responsible for the occurrences of slope failures. Like collapse of Highland Tower (1993) has no clear geological or morphological cause. It is reported that inadequate factor of safety along with improper construction is the major cause [11], [12]. A prominent case of Bukit Antarabangsa (2008) also having no geological factors, this is the case of improper drainage facility with no proper maintenance. Inadequate designing, inappropriate construction methods are often rampant. Above mentioned two events are not only among the prominent cases, since 1993 till this date these incidents are continuously happening. Time stress, lack of resources, Novice/ unqualified Personnel, organizational factors or what are the prevailing factors? These are the questions that are required to be probed.

II. Data Collection and Methodology Development

Through some expert interviews and opinions, (belong to consulting firms and some from ex staff of concerned division (Slope engineering division), the list of contributing factors have been prepared in this regard as it is the major requisite of this study. Concerned officials also furnished this research by giving the estimated percentages of selected error generating conditions. Despite the fact, insufficient data results may not be adequate completely, but at least the contribution of human factors leading to greater increase in landslides can be highlighted and evaluated.

Considering the history of Malaysian slope failures or the causes of its instability, its causative factors have been provided by concerned consultants on the request of the author. Author considers it's more authentic as compared to baseless and arbitrary predictions. The criteria of their expertise and eligibility have been set according to experience, reputation and standing in the profession, willingness and availability to act as an expert, locality and publications of the experts. These set standards are not new as it is a general practice in the choice of real experts. The opinions have been collected by an interview administered questionnaire. Here author follows Aggregated Individual Method to work on the expert's opinion strategy. This method is preferable as the opinions obtained through Aggregate individual method are independent. Secondly the author considers it less time consuming. However at few places Consensus Group Method is also followed for the purpose of validation

It is known through personal communication that most often without designing of slopes, drawings are provided for construction. (Due to time pressure/work load). It comes under the category of individual's attitude but basically this reflects the attitude of the organization towards the personnel in charge. Excessive workload and time constraints both are the main prompting factors. At a single point of time, a design engineer is dealing with hundreds of projects, it's totally impossible that an authentic spotless design can be produced considering the pragmatic realities of onsite working.

One of the responsible personnel of Slope engineering division suggests that design errors can be countered in the phase of construction also if recruitment of some qualified and experienced personnel inspection would oversee the activities. Since a loophole during the supervision phase is the main error generating factor, it should be properly executed to obviate subsequent problem.

A total of 27 influencing factors/Performance shaping factors (PSFs) (Table I) are identified by experts, on the basis of their experience and judgments in distinct phases of design, construction and maintenance

TABLE I. Sources of Error in Three Distinct Phases

Design Phase	
No	**Behavioral/Technical Sources**
D1	Time constraints
D2	Avoiding new codes /software's used in designing
D3	Poor coordination among the personnel
D4	Unhealthy working environment
D5	Individuals attitude
D6	1V:1H gradient provided without considering slope height
D7	Inaccurate soil parameters
D8	No previous record
D9	Unclear standard/codes
D10	Application of unsuitable procedures without considering its effects
Construction Phase	
No	**Behavioral/Technical Sources**
C1	Improper sequencing
C2	Lacking in supervision
C3	Poor working environment
C4	Personal reasons
C5	Over excavation/Improper method of excavation
C6	Inadequate temporary support
C7	Excessive construction loads
C8	Material deficiency
C9	Application of new technology
C10	Aged/poorly calibrated equipment
Maintenance Phase	
No	**Behavioral/Technical Sources**
M1	Poor communication
M2	Financial matters
M3	No awareness of consequences
M4	Unsuitable maintenance criteria
M5	Following outdated strategies
M6	Weak decisive power
M7	Unskilled force

III. Results and Discussion

There are more than 30 Error Producing Conditions (EPC) provided in HEART [13] technique for matching with identified Performance Shaping Factors (PSF) shown in Table I. Most of them are very common in use like time stress, unfamiliarity, poor feedback, poor procedures etc. The Calculation of HEART is dependent on generic error probability and related EPC's. Generic error probability has to be selected from the given criteria A-H [13] according to focus situation EPCs carrying a maximum affect value, which has to be changed with the estimated proportion.

In the analysis, generic error probability has been selected, by keeping in view the designing of slope into consideration. Since slope designing and its fixation is not a very complex task, especially in the hilly areas where plain land in scarcity is a routine practice. In this context Generic task of category E is suitable for this analysis carrying unreliability of (0.007-0.045). Here in Table II, Table III and Table IV average value of 0.026 is considered for Generic Task Type (GTT). In the second column of Table II, Table III and Table IV EPC values are selected through matching strategy. For example, time constraint is one of the design error source match it with EPC of time stress carrying a maximum value of 11 reported in the literature [13]. Proportion of this value has been estimated by experts opinions and a mean value is applied as given in column 3 (APOA). As compared to other error rate prediction techniques it is quite easy and reliable. It requires only the perception of the user; no detailed calculations are involved in it. Its validity and accuracy is already confirmed through a large scale study of 30 tasks [14]. This can be applied to any industry where the human reliability has to be checked [15]. A simple process is worked out on the basis of the following Eq. (1).

$$HEP= GTT\ [(EPC-1)*APOA+1] \quad (1)$$

EPC=Error Producing Condition

GTT=Generic Task Type

APOA= Assessed Proportion of Affect

TABLE II. DESIGN PHASE HEPS

No	Matching EPCs	Total	APOA	HEP
D1	Time shortage	11	0.25	0.07
D2	Lacking in information	9	0.4	0.084
D3	Inadequate conveyance of information	8	0.1	0.034
D4	Poor or disorganize working	1.15	0.1	0.0203
	environment			
D5	Behavioral/work stress	1.3	0.25	0.0215
D6	Mismatch between education and task	2	0.6	0.032
D7	Unreliable instrumentation	1.6	0.6	0.0272
D8	No feedback or poor feedback	4	0.4	0.044
D9	Ambiguity in the standards	5	0.4	0.052
D10	Inconsistency between displays	1.2	0.6	0.0224

TABLE III. CONSTRUCTION PHASE HEPS

No	Matching EPCs	Total	APOA	HEP
C1	Inconsistency	1.2	0.4	0.0216
C2	Little consideration /importance given	1.8	0.25	0.055
C3	During activity no monitoring or follow up	1.15	0.1	0.203
C4	NA	NA	NA	NA
C5	No preference	1.4	0.6	0.0203
C6	No meaning or preference for given task	1.4	0.4	0.0248
C7	Mismatching in estimation	4	0.1	0.0232
C8	No preference or checking the quality of material	1.4	0.6	0.026
C9	NA	NA	NA	NA
C10	Unreliable instrumentation	1.6	0.4	0.0248

TABLE IV. MAINTENANCE PHASE HEPS

No	Matching EPCs	Total	APOA	HEP
M1	Inadequate conveyance of information	8	0.4	0.07
M2	NA	NA	NA	NA
M3	Mismatch/misjudges about risks	4	0.4	0.034
M4	Inconsistent/unsuitable standards	1.2	0.6	0.0203
M5	Unclear allocation	1.6	0.25	0.0215
M6	Need absolute judgment	1.6	0.4	0.032
M7	Mismatch between capacity and capability	2	0.6	0.0272

NA= Not Available

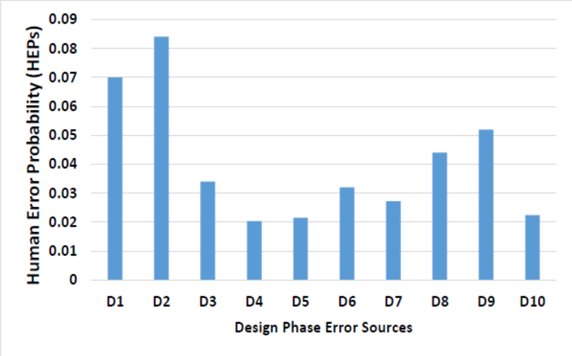

Figure 1. Comparison of design phase HEPs

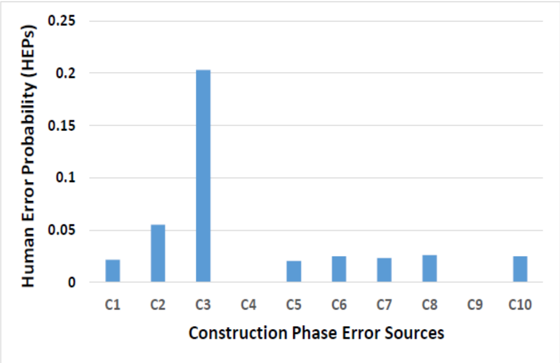

Figure 2. Comparison of construction phase HEPs

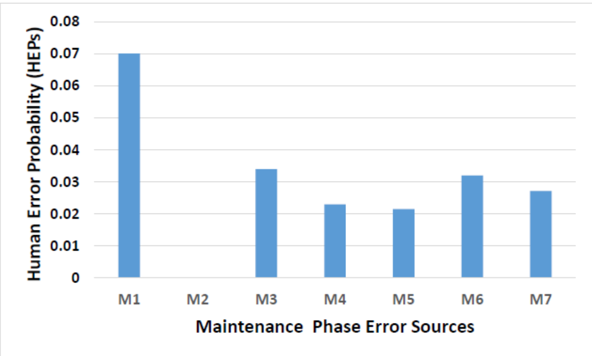

Figure 3. Comparison of maintenance phase HEPs

Among other design error factors time constraint is dominating according to HEART technique (Fig. 1). Time constraint itself is nothing but due to this influencing factor mistakes in designing of slopes arises. It may be slips, skip a step or calculation error. These types of errors can be sorted out easily if trend of checking persists Detection of error or error recovery is not the only issue but identification of the error, means its type has to be noted as severity relates to potentiality. Similarly, in construction phase (Fig. 2), errors can easily be rectified, if framework of four major steps of inspection, communication, decision and action (ICDA) has to be adopted for every going on activity. To some extent, Peck and other researchers also favored the same strategy of observation for every ongoing construction. [16], [17]. In terms of maintenance (Fig. 3), only inspection/observations cannot be enough, in time communication and rapid action must be there.

IV. Conclusion

Decisions and actions should be taken at first preference. Proper and timely maintenance of slopes sometimes will cover the design flaws also. This study evident that the opportunity to control error sources in relation with slope failures exists. The proposed frameworks of all three major phases will make the errors to acceptable limits, only motivation and strict follow-up is needed

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