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Human Error Quantification Techniques: A Brief Review

S. Qasim and I.S.H. Harahap
Department of Civil Engineering, Universiti Teknologi PETRONAS, Bandar Seri Iskandar, 31750 Tronoh, Perak D.R., Malaysia

Abstract: Insert Quantification of human errors is not an easy task in any of the industry. With reference to construction industry, due to scarcity of databases no proper move until now has been done. But without databases it seems quite possible to quantify the human errors as behavioural aspects of humans more or less the same in every industry. The main aim of this study is to pinpoint the negligence of geotechnical/construction industry in relation with human errors or human uncertainties. Till now no concept of taking Human reliability analysis into consideration, in spite of their beliefs that human errors/human uncertainty exists. Human reliability analysis proposed different models and methods to pinpoint and quantify human performances as human performances sometimes becomes big threat to structural reliability. Slope failures/slope instability is also most of the times are the outcome of deficit design, flaws in construction or poor maintenance of the structures used to strengthen the slopes. Among different techniques discussed in this study, author's choice is to recommend the model of heart for Human Reliability Assessment. The reason of selecting this model of heart is transparent, as this model has also been tailored before by Air Traffic Management and Railways. In other words it works well or it has the flexibility to adjust with any other industry.

Keywords: Human errors, human reliability analysis, probability of failure, structural reliability analysis

INTRODUCTION

Quantification of human errors is not an easy task in any of the industry. With reference to construction industry, due to scarcity of databases no proper move until now has been done. But without databases it seems quite possible to quantify the human errors as behavioural aspects of humans more or less the same in every industry. As stated by Kariuki (2007) that in the chemical process industry the sources of HEP statistics are principally from the nuclear industry and expert judgement. And as long as the lack of HEP data continues these two sources of data will remain functional. This shows that use of other industries databases at least provides a tentative or estimated figure about human error probabilities.

Human reliability analysis proposed different models and methods to pinpoint and quantify human performances as human performances sometimes becomes big threat to structural reliability. As already pointed out by Frangopol (1986), (Lind 1982) and Melchers (1984), that gross (human) errors bring changes in the probability of failure.

A Swedish study, commenced in 1995 is to make known the extent and reasons of class blemish costs in structural projects. It discloses that about three-quarters of the total amount of faults are in design and construction phases, while the rest quarter is from, reasons of owner, material release, equipments and staff. Roughly 60 % of the faults (Fig. 1) could be interrelated to lacking in commitment and less than 20 % each one to scarce information and not enough knowledge, respectively (Josephson and Hammarlund, 1996a; Josephson and Hammarlund, 1996b). The straight cause might primarily be accredited to individuals. Yet, every act by an individual is governed by a crowd of conditions or performance shaping factors it can be sometimes positively works but most of the times it contributes negatively.

Slope failures/slope instability is also most of the times are the outcome of deficit design, flaws in construction or poor maintenance of the structures used to strengthen the slopes (Jamaluddin, 2006). Malaysian report itself admitted that, among 49 major cases of landslides 88% are accredited to manmade slopes (JKR, 2009). Gue and Tan (2007) also approved that along with poor designing, incompetency, negligence, raw input data are the responsible agents of these slope failures. No doubt this reality is not accepted truly that uncertainties related to human has also to be observed. In spite of that researchers thought that human uncertainties are also dominant in geotechnical industry. Due to these prevailing factors human

Corresponding Author: S. Qasim, Civil Engineering Department, University of Technology Petronas, Bandar Seri Iskandar, 31750 Tronoh, Perak D.R., Malaysia

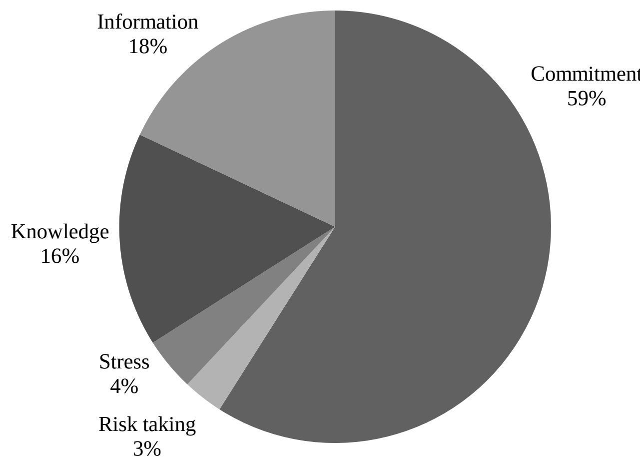

Fig. 1: Causes of faults in structural systems (Josephson and Hammarlund, 1996a)

Fig. 2: SKR model (Rasmussen, 1982)

reliability analysis or likelihood of human errors in different phases of design, construction and maintenance has to be determined.

Consideration of human errors whether it is technical based or attitude dependent has already been predicted or quantified by different estimation techniques like Human Error Assessment Rate Technique (HEART). Technique for Human Error Rate Prediction (THERP) and Success Likelihood Index Method (SLIM) in nuclear power industry and chemical industry. Already in hand data bases of nuclear power industry and chemical industry in one way helping other industries to check the influence of human errors. It is obvious now that role of humans not only in safe operation of complex industrial plants but also in airways, railways and in construction industry too is deeply involved.

The objectives of this study are:

- To accentuate the role of human errors by discussing human error models and human reliability analysis techniques
- To pinpoint application of human reliability analysis approaches in nuclear power plant, chemical and Off shore industries
- To confirm a need of human reliability analysis in geotechnical/construction industry by putting numerous devastating failures into discussion

HUMAN ERROR MODELS

Human error models, divided human errors into two sections, slips and mistakes. Slips are referred as unintentional errors, defined as unintended performance of an action. Mistakes lie under the category of deliberate actions means; knowingly do inappropriate selection or choice in the system.

Rasmussen SRK model: The model (Fig. 2) has taken human errors into three segments. Skill based, rule based and knowledge based (Rasmussen, 1982):

- **Skill based:** Acts involve the most minuscule level of cognitive job for example doing much known operations.
- **Rule based:** It needs more concentration as compared to skill based acts. An example of the skill required at this point is to remind or recall the suitable rules for non familiar jobs.
- **Knowledge based:** Acts under this level require full concentration and consciousness. Mental capabilities / full knowledge have to be consumed to analyse or solve the issues.

Reason (1990) model: In actual violations are deliberate actions, knowingly deviated from safe guidelines or procedures. Unintentional acts may be disordering, mistiming, intrusion reveal or omission. It all lies under slips. Lapse is basically forgetting, omitting planned issues or place-losing. Intended acts shows misapplication of rules/standards, or avoiding specifications. Violations are on routine or on an exceptional basis. The summarized view of violations/unsafe acts is shown in Fig. 3.

Human reliability approaches: The approaches to calculate human reliability have occupied two categories: one looped with databases and other totally relying on expert's opinion. The first category consists of those techniques which has already in hand generic error probabilities. These generic probabilities are than manipulate by the evaluator to extrapolate from the generic data to the particular scenario being considered. Manipulation is usually stood on assessor's judgment of situation governing Performance Shaping Factors or Error Producing Conditions. Techniques lie in second category are not so structured, totally relying on personal communication and asking to estimate the probabilities of the specific situation. Examples of these category techniques are Absolute Probability Judgement (APJ) and Paired Comparison (PC). Success Likelihood Index Method is also belongs to second category but this technique follows a structured pattern. The generation of HEPs may therefore arise through expert's opinion or by combination of assessor's manipulation and interrogation of quasi-databases (Kirwan, 1998). The most commonly used techniques are described below.

Technique for Human Error Rate Prediction (THERP): This technique uses a database of error probabilities tailored by the assessor by using Performance Shaping Factors. The process of quantification is shown in Fig. 4. The key points of this technique are:

- Decomposition of tasks into elements and allot nominal HEPs
- Find out the influence of PSFs on each element
- Determination of effects of dependence between tasks
- Using Event tree analysis for modelling and quantifies total task by HEP

The selection of nominal HEPs according to the considered task/element is carried out with reference to Chapter 20 of the handbook of THERP. It is one of the followed techniques used in Nuclear Power Plant and Reprocessing industries (NP&R) in U.K adapted from (Kirwan, 1996a).

Human Error Assessment Rate Technique (HEART): There are more than 30 Error Producing Conditions (EPCs) provided in HEART technique for matching with identified PSFs related with the focused task (Performance Shaping Factors). Most of them are very common in use namely time stress, unfamiliarity, poor feedback, poor procedures etc. Calculation of HEART is dependent on generic error

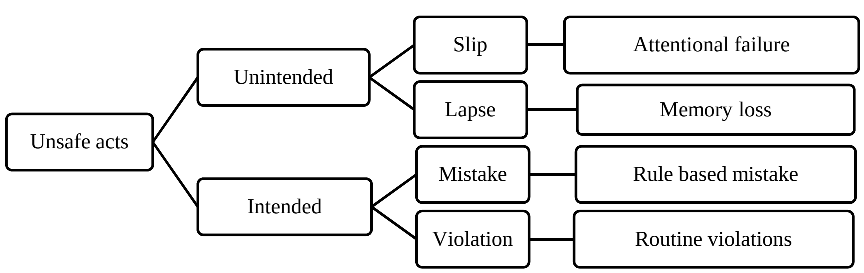

Fig. 3: Unsafe acts (Reason, 1990)

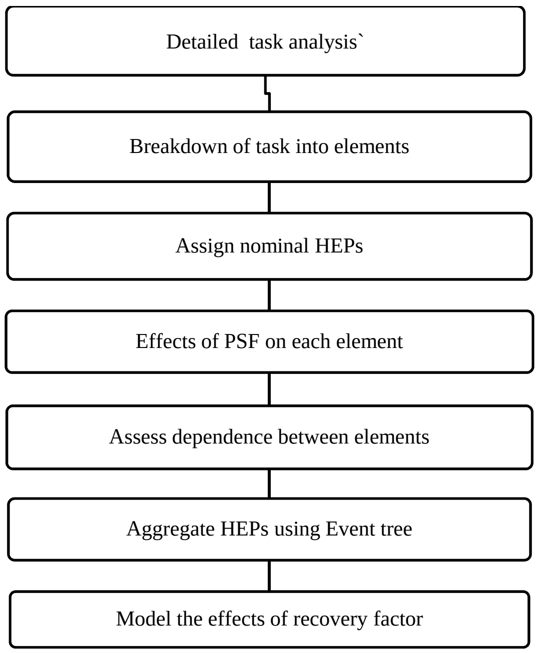

Fig. 4: THERP process (Kirwan, 1996)

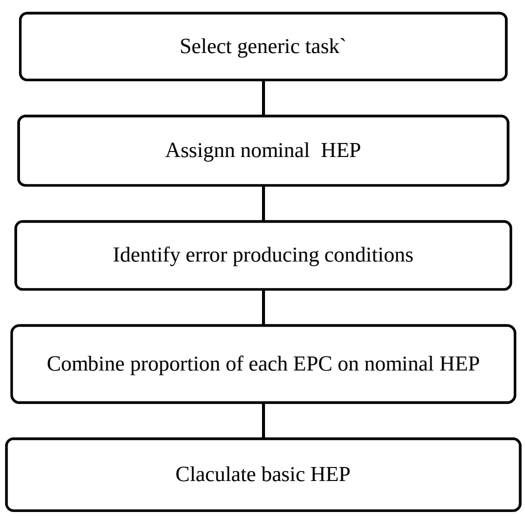

Fig. 5: HEART technique (Williams, 1986; Williams 1988

probability and related EPCs. Generic error probability has to be selected from the given criteria A-H according to focus situation EPCs carrying a maximum affect value, which has to be changed with the estimated proportion. Proportion of this value has been estimated by expert's opinions and a mean value is applied (Fig. 5).

As compared to other error rate prediction techniques it is quite easy. 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 (Kirwan, 1998). This can be applied to any industry where the human reliability has to be checked. No doubt due to insufficient data results may not be so sophisticated but at least what human factors are more influential can be assessed by applying HEART technique. This technique serves in determining human error probabilities (Kirwan, 1998).

Human Error Probability (HEP) is defined as number of errors occurred divided by the total number of opportunities to occur. Nominal HEPs can be derived out by using a record of total events with number of events occurred due to human errors (without considering human factors). This can be called as raw human error probability. In calculating basic Human Error Probabilities (HEPs) proportion of Error Producing Conditions (EPCs) must be included.

A simple process is followed on the basis of the following formula (Kirwan, 1998):

$$\mathrm{HEP} = \mathrm{GTT}\,[(\mathrm{EPC} - 1) \times \mathrm{APOA} + 1] \quad (1)$$

EPC = Error Producing Condition
GTT = Generic Task Type
APOA = Assessed Proportion of Maximum Affect

Controller Action Reliability Assessment (CARA): This technique is basically on the format of HEART technique (Williams, 1986). It is utilized to quantify human performance in Air Traffic Management. According to focussed environment CARA (Gibson and Kirwan, 2006) modified HEART technique by generating its own GTTs and EPCs. HEART has been selected as a model because it has been the subject of confirmation exercises (Kirwan *et al*., 1997) and the significance and compliance to different domains is propping up by recent developments of HEART in nuclear industry (Edmunds *et al*., 2008) and railways (Kim *et al*., 2006).

Success likelihood index method: It is a pure judgment base but structured technique, without experts' opinions and discussions it can't be run. Visualize the event and sub events and the rating and the weighting of the concerned PSFs all requires expert's panel. Consistency level between their decisions will also not be overlooked. It's very easy to define but not easy in execution. On the basis of PSFs ratings and weights Success Likelihood Index (SLI) is determined. SLI in original is the product of weight and rate of single event. Conversion of SLI values into probabilities also needs logarithmic relationship. This technique has now computer version named MAUD. MAUD stands for Multi Attribute Utility Decomposition helps to cover the biases of judges' opinions and decisions (Bell and Holroyd, 2005).

Human Error Probabilities Index (HEPI) is also predicted through this technique of SLIM (Fig. 6) in offshore events. Due to scarcity of database, a panel of 24 experts is selected to work out the rating and

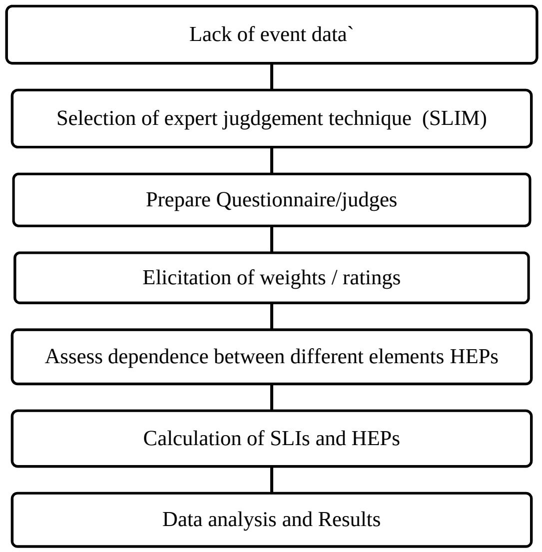

Fig. 6: SLIM technique (Grozdanovic, 2005)

Table 1: Comparisons of techniques (Kirwan, 1994)

Criteria	THERP	HEART	SLIM
Accuracy	Medium	Medium	Medium
Validity	Medium	Medium/high	Medium/high
Usefulness	Medium	High	High
Effective use of resources	Low/ Medium	High	Medium

weighting of the governing PSFs. PSFs are stress, complexity, training, experience, event factors and atmospheric factors, Rating scale or weighing criteria for PSFs is provided as a guide to direct the experts (DiMattia *et al*., 2005).

For a specific muster action, weight of each PSF is modified by dividing the sum of the weights of all the PSFs for that action. The final output success likelihood index of the specific action is then obtained by multiplying the rating and modified weight of that particular PSF. For specific action six values of SLIs are determined, the summation of all these 6 values gives a total SLI value of that considered action. The higher the SLI value the greater the chances of successfully accomplishing the action. After having the SLI values, next step is to estimate the HEPs by taking logarithmic relationship:

$$\log(\mathrm{POS_i}) = \mathrm{a}(\mathrm{SLI_{i.m}}) + \mathrm{b} \quad (2)$$

(POS_i) = 1-HEP_i (Probability of success for action i)
$SLI_{i,m}$ = Arithmetic mean of Success likelihood index values of action i
a,b = Constants

Constants 'a' and 'b' needs two basic HEPs of an action carrying highest and lowest SLI values. For Basic Human Error Probabilities (BHEPs) three approaches are there:

- Empirical BHEPs from limited available master data
- Elicited HEPs from randomly selected subset of elicited review team
- THERP data of Swain and Guttmann (1983) and Kirwan (1994)

Among several techniques, HEART, SLIM and THERP are widely applied in taking nuclear power plants and offshore scenarios. These techniques no doubt differ with each other at different levels (Table 1) like suitability, validity, accuracy and effectiveness (Kirwan, 1994).

Qualitative Simulation with Human Reliability Analysis: The core intention of HRA is to accurately weigh up risks generate from human error and to gaze for ways to condense force of human error. In special cases, the outcome objective of Human Reliability Analysis should be to work for reasons of reliability decline produced from human error and approaches to overcome them (Kirwan, 1994). As a result, it shows divergence from HRA into Human Error Analysis (HEA). A complete HRA process must have the following steps:

- Recognition and description of human error
- Quantification of human error probability
- Analysis of human error modes and effects
- Design and authentication of protective measures for human error

Human reliability analysis in complex industrial processes is in front of difficulties, such as deficient knowledge utilization and simplex methodical means etc. The research of Long *et al*. (2009) clarifies basic meanings and current progress position of human reliability analysis and qualitative model correspondingly and then on the foundation of it, considering existing deficiency of human reliability analysis approaches, the research of Long *et al*. (2009) in actual publicize the essentiality to relate qualitative simulation with human reliability analysis by proposing framework (Fig. 7). In the proposed framework factors of task (T), man machine interaction (Q), Training level (T), Environment (E) and work time (t) has been compared in correspondence with actual and expected ability. It supports qualitative simulation of exposes returns in making uncertain message and "Deep" knowledge in the fields of supporting analysis and decision making and has grow to be a kind of effectual methods in fixing incomplete knowledge. There are sense inevitability and genuine achievability to pertain qualitative simulation into HRA.

Human reliability analysis applications: A case history of existing nuclear power plant in connection with human reliability assessment is pinpointed. The HRA has taken up all steps from problem description and task analysis through error identification and

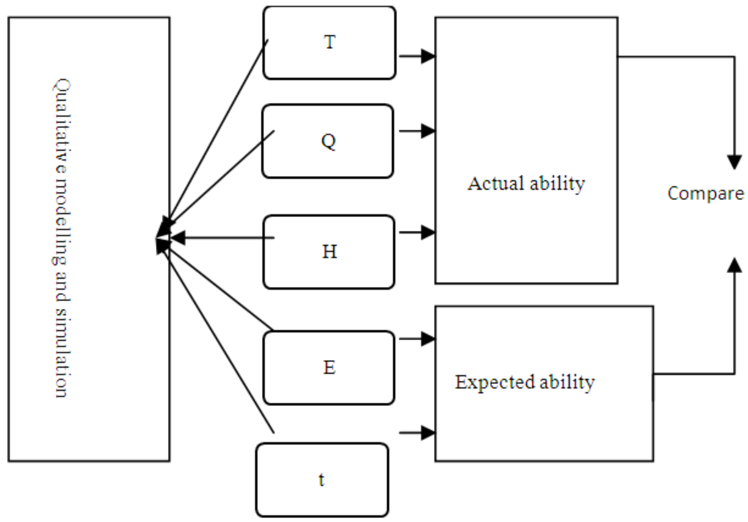

Fig. 7: Framework for qualitative study (Long *et al*., 2009)

quantification to impact assessment error minimization, quality assurance and documentation. In the study of Kirwan *et al*. (1996b) a methodology of HRA with respect to Probabilistic Safety Assessment (PSA) is proposed. The primary focus of PSA is on operational or equipment weaknesses/flaws in nuclear power plant and to work out plans of how to wipe out these weaknesses. HRA along with human factor or ergonomics also has the capacity to read design procedures, training vulnerabilities and to indicate ways for its rectification. This is called error reduction. Quantitative evaluation of all the contributors to risk can be assessed by Fault tree or event tree analysis. Error reduction can target only particular errors. A specific Performance shaping factor is considered only, when, it repeatedly originating a number of disparate errors. This type of error reduction approach is referred as strategic error reduction.

Cognitive errors examples are wrong diagnosis or late diagnosis. Errors of commission are those actions which are not required by the system. These errors are of prime importance in nuclear power plant industry. As incident of Three Mile Island divert the attention towards this aspect also.

In connection with crew and operators action of nuclear power plant industry a cognitively supported human reliability assessment technique for calculating the HEPs has been discussed (Blackman *et al*., 2008). The method Standardized Plant Analysis Risk – Human Reliability Analysis (SPAR-H) is used to quantify human performances at nuclear power plants. SPAR-H is the product of Technique for Human Error Rate Prediction (THERP) and. Accident Sequence Evaluation Program (ASEP). Human Reliability Analysis Procedure (ASEP) is also the simplified version of THERP. SPAR-H method focuses on two aspects, diagnosis or action. Action oriented task includes operations, calibrations testing etc. Diagnosis tasks refer to planning and prioritizing activities, using knowledge and experience to read the existing conditions. This method has pre defined nominal HEPs which has been modified by the application of related PSF multipliers. (Boring and Blackman, 2007) presented the history of these multipliers. SPAR-H uses eight PSFs having multipliers typically corresponding to nominal, degraded and severely degraded human performance for individual PSFs. In the absence of PSFs nominal HEPs for diagnosis and action refers to 1E-2 and 1E-3 respectively. Till now HRA proposed 50 PSFs as used in IDAC (Mosleh and Chang, 2004; Mosleh and Groth, 2009) model, SPAR-H methods according to nuclear power plant requirement selected initially 6 than 8 PSFs. Selected PSFs includes:

- Available time
- Stress and stressors
- Experience and training
- Procedures
- Complexity
- Fitness for duty
- Work processes
- Human machine interaction

Few of the PSFs and its multipliers are given below as an example. Referring to experience and training; three levels low, nominal and high are in use to set the multiplier. High level shows extensive experience and perfect knowledge to tackle the situations and a value of 0.1 is used to modify HEPs. In case of low and nominal levels multipliers of 10 and 1 are taken. In this governing PSF of experience and training period of 6 months or more than 6 months are adjusted with low and nominal levels. Stress and stressors also have three main levels; extreme, high and nominal carrying values of 5, 2 and 1, respectively. Environmental factors such as heat, noise poor ventilation are also the source of stress to operators. Talking about fitness for duty again three levels unfit, degraded fitness and nominal exists with this PSF. First level of unfit shows no margin as individual is unable to perform, the probability of failure in this case is 100%. For rest of the two levels, multipliers of 5 and are fixed. Work processes also carry three levels of poor, nominal and good with multipliers of 2, 1 and 0.8, respectively.

Need of human reliability analysis in geotechnical/construction industry: According to its mode of occurrence human errors in structural reliability are classified as:

- Conceptual errors
- Errors in execution
- Intended errors

Conceptual errors are basically unintended errors, due to insufficient knowledge. It is defined as the departure from the accepted practices unknowingly. Execution errors are the result of unpremeditated departure from the conceptual model existing in the mind of the contractor or designer. Intended errors are planned errors (El-Shahhat, 1995).

In discussion of 500 failure cases 58% attributed to design errors 38% is originated from construction, 4% in operation. Approximately half of the errors are from design and second half refers to construction. Three causes are identified, absence (12%), ignorance (33%) and rejection of modern/current technology (55%) (Sowers, 1993). Melchers (1984) reported through evidences that structural resistance suffers due above mentioned errors. Human errors in design and construction process turn out a low resistant structure than actually expected. It is also agreed that a large share of structural failures are due to human error in the design stage of any of the structural project and many of these failures could have been ward off if there had been passable design checking (Stewart and Melchers, 1989). Results are furnished from surveys probing the usefulness of three classical design-checking strategies: self-checking, independent detailed design checking and overview checking. Following a reconsider of present work in this locale, fitting mathematical models, which scan the effects of error magnitude, times and experience, are wished-for for each design checking process. (Frangopol, 1986) has taken human errors into probabilistic models. At first error free reliability index is computed than it modifies by accounting human errors. In calculating structural risk always start from an ideal case of having error free system. Lind (1982) has also proposed three mathematical models (like discrete model, error filter and elimination model and error combination) model to counter human errors for maintaining maximum reliability of the structure.

In relation with structural failures, one very debatable observation is that their occurrence is knowledge based. Unknown knowables and unknown unknowables are two categories of this knowledge based challenges (Bea, 2006). The first category is already discussed by Sowers (1993) as rejection or technology misuse. Second category belongs to limitations in knowability. Potential of an engineer is limited for the extraction of knowledge. Sowers (1993) and Bea (2006) discussed four quality objectives serviceability (i = 1), safety (i = 2), compatibility (i = 3) and durability (i = 4) with respect to six life cycle processes concept development, design, construction, operation, maintenance and demolition. In this aspect failure probability is:

$$P(F_i) = (D_i \geq C_i) \tag{3}$$

D_i = The demand placed on the system
C_i = Capacity of the system to fulfil the demand

The probability of failure with respect to quality attribute (*i*) due to essential nature (*I*) or non essential nature factors (*E*) is:

$$\mathrm{P(F_i) = P(F_{iI} \cup F_{iE})} \tag{4}$$

Non essential nature extrinsic factors can also be excluded or managed through Quality Assurance and Quality Control QAQC. Base rates of extrinsic factors, category of Performance Shaping Factors are necessary features of Quality Management Assessment System (QMAS). Qualitative grading of QMAS and its conversion into quantitative Performance Shaping Factors (PSFs) is shown in Fig. 8.

The European Federation of National Maintenance Societies described maintenance as: All actions which have the goal of reinstating or retaining an item in or to a state in which it can execute its essential function. The actions consist of all technical, administrative managerial and supervision actions.

Janney (1986) defined structural failure as: “The reduction of the capability of a structural system or component to such degrees that it cannot safely to serve its intended purpose”.

Human factors which contribute in structural failures/errors are given in Table 2. Three very basic tasks are selected by Melchers (1984) to search the evidence that whether the involvement of humans exists or not in deficit design.

- Table look up
- Numerical work
- Ranking of numbers

Table 2: Structural failures/errors (Melchers, 1984)

Concept errors	Random/systematic			
	Modelling	Random/systematic		
Design errors	Calculation	Random/	systematic	Computational
		Random/systematic		
	Discretization	Random/systematic		
	Table-use error	Random/systematic		
	Code interpretation	Random/systematic		
	Code validity	Random/systematic		
	Data interpretation	Random/systematic		
Design-construction interface	Random/systematic			
Construction errors	Random/systematic			
Usage errors	Random/systematic			

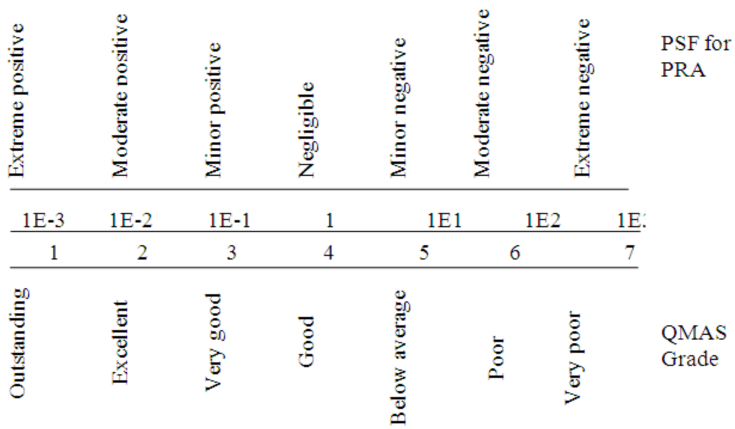

Fig. 8: Quality management assessment system (Bea, 2006)

These tasks comprise of member selection from tables (task 1), simple stress calculations (task 2) and matching with pre defined criteria (task 3). The errors are classified as random or gross errors. Gross errors reflect in those values which depart more than 2.5% from correct values. On the basis of these tasks error rates are determined which is quite agreeable when compared with the range of values of other error rates of psychoomotor tasks.

Even the study has been condemned due to its unsophisticated pattern: taking students as subject to fill the questionnaire, very few data points etc but the results are more or less similar. No doubt care has been taken like vague replies are not entertained, time frame is focussed and the purpose of this task has not been communicated to the students.

By an event tree process having all the design steps, taking into account all the branches implied by omission errors and the variability due to commission errors. The reliability of design along with human error inclusion can be estimated by this method. The total probability of failure is obtained by adding the probabilities determined for descending via all possible combinations in event tree.

In few studies human errors has been discussed in an indirect manner, for example among 143 bridge failures, 70 is claimed due to foundation movement, 22 by unsuitable or defective material and so on (Smith, 1977). The researcher does not point out human errors. Matousek (1977) in contrast to Smith (1977) concluded that human errors always there in a sample of 800 cases. An example of the catastrophic failure of Kwun Lung Lau landslide in Hong Kong is also the input of human uncertainty (Morgenstern, 1995). Most of the cases of Malaysian landslides for example Highland Towers in 1993; Bukit Antarabangsa in 1999; Bukit Antarabangsa in 2008 are also the ending are also the result of improper safety factor, poor or non maintained drainage facilities (JKR, 2009). Discussing about the documentation and analyses of construction failures (Yates and Lockley, 2002) reported the division of construction failures into two categories: technical and procedural, technical causes/failures are real material proximate causes like improper soil compaction results in excessive settlement. Procedural causes directly involve humans as due to miscommunication or flaws in designing and construction. These procedural errors are in actual responsible for physical failures. Organizational issues are also related here as when soil testing laboratory fails to check the compaction of the soil. The division of structural failures has been taken place into three general categories of functional, safety ancillary and its belongs to causes into five general areas (Thornton, 1985):

- Deficit design
- Construction flaws
- Material deficiencies
- Organizational/administrative shortcomings
- Improper/poormaintenance

Table 3: Construction industry error sources (Atkinson, 1999)

Primary	Knowledge/training/education Selection of knowledgeable personnel Self inspection of task
Managerial	Checking work Dividing responsibilities Controlling change Controlling concurrent working Communication
Global	Organizational culture Economic pressure Time pressure Political pressure Societal pressure

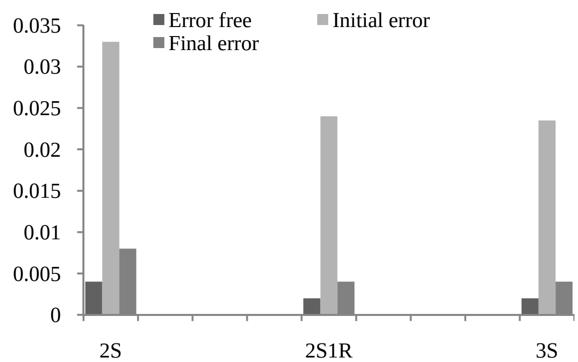

Fig. 9: Human errors before and after inspection (Epaarachchi and Stewart, 2004)

Observational method (Peck, 1969) is best suitable for every ongoing construction but it only suits when design alterations are possible. Haydl and Nikiel (2000) also pinpoint by taking case histories which refers construction failures, due to redundant bracing, wrong assumption of the design engineer, improper sequences or at an eleventh hour c hanges.

Through field survey and unstructured interviews the fact is exposed that managerial influence is more dominating in defects of construction industry (Table 3). Errors committed during operations and supervisions are not only one man show. In a construction industry methodical literature review from technological, social science and management perspective has been directed to develop three stage models of error sources (Atkinson, 1999).

The findings prove that communication is the most significant source of error production. It is rated very high in lieu of other error sources. Primary factors are throughout important but at the management level its importance is highly concerned. One interesting fact also comes to know that experience without knowledge/qualification has got no weight age. Most often inexperienced but qualified personnel take right/ better decisions. Inexperienced managers having sound educational background reported lower level of defects. The safety of reinforced concrete structures is of major concern during construction. Human errors types such as inadequate pouring of concrete, untimely removal of formwork, concrete cover inadequacies, poor quality of supervision create major negative effects. The Swedish study (pinpointed slightly, in Section 1.1) reveals the causes of quality fault costs in building projects (Josephson and Hammarlund, 1996a; Josephson and Hammarlund, 1996b). Seven different building projects are studied and overall of 2879 faults are detected. Each fault is pen down along with essential information regarding explanation of fault, building component part involved, fault origin, i.e., which part of the building process was responsible, primary cause fault type. The faults are categorized according to type of work performed, with approximately 120 faults beginning from gathering of formwork, 70 faults from reinforcement task and 180 faults from concrete casting.

Examples of faults starting from connecting of formwork:

- Wrong position of construction joint (cause: knowledge)
- Recess in construction joint not carried out(cause: commitment)

Examples of faults coming out from rein for cement:

- Wrong rein for cement approved (cause: commitment)
- Recesss trip mislaid (cause: information)

Examples of faults basis on concrete casting tasks:

- Wrong quality of concrete transported (cause: commitment, information)
- Casting flaws (cause: commitment, unavoidable due to existing knowledge, method and equipment)
- Improper curing of concrete wall (cause: time pressure)

One of the study presented probabilistic and human reliability models. The models used to estimate the system risk during construction due to human errors. Error control measures in terms of inspection are judged by taking two cases: system risk before inspection and system risk after inspection (Fig. 9). Sensitivity analysis is also executed to conclude the effects of individual or multiple errors on system. A common issue in reinforced concrete constructions is that, a same error crop up more than once. System risk has been evaluated on three shoring systems denoted as 2S, 2S1Rand 3S. It is clearly speaks out from Fig. 9 that changes in the initial errors after inspection is around 70 to 80%. This shows that some errors can be easily sort out if proper follow up of the work exists. Final error human reliability models are used for Sensitivity analysis. Through sensitivity analysis it is noted that due to inaccurate concrete cover, system risk increases up to 45% among other error rates. This is the most alarming increment in system unreliability. Due to poor concrete workmanship system becomes unreliable up to 25% but very minute effects are measured due to premature removal of shoring. This is maybe due to low error magnitude. In case of combination with different sort of errors premature removal of shoring poses dramatic change. The system risk is lowered down up to 10% if the above mentioned particular error is not taken into consideration. System risk is in actual the probability of structural failure/collapse during construction due to human errors.

It is also quite clear now that construction cycle will affect the system risk as punching shear is dominant for final error risk system. Concrete strength will become lower due to cut short of construction cycle.

SUMMARY AND CONCLUDING REMARKS

Slope engineering is fully focusing nowadays due to increasing number of landslides. Most of the landslides occur on manmade slopes and this is basically the result of deficit design, flaws in construction or poor maintenance (Jamaluddin, 2006). In one of the sectoral report of Malaysia, among 49 major cases of landslides 88% are accredited to manmade slopes (JKR, 2009). (Gue and Tan (2007) also agreed that along with poor designing, incompetency, negligence, raw input data are the responsible agents of these slope failures. Till date this fact is not accepted truly that uncertainties related to human factors has also to be tackled. In spite of that researchers believed that human uncertainties are also dominant in geotechnical industry.

Taking of human reliability analysis into consideration is due to cover the known fact that probability of failure drawn from structural reliability analysis is conditional. This is basically one of the assumption put forwarded by Schneider 1997) in one of the restrictions. The two restrictions are repeatedly taken when calculating failure probabilities. Firstly variables in a limit state function are self-governing, not depends on each other, as associations among the variables significantly impenetrable the calculations, secondly failure probabilities are ephemeral or conditional assuming that no human errors be real in what is analysed. Although, human influence is very much caught up in the planning, designing, constructing and maintaining of any of the structure and it seems quite alarming if considers it in a dormant mode.

Broadly speaking reliability of the slopes has to be assessed not only through structural probability of failure but probability of failure due to human errors has also to be considered. As it is mentioned in by that structural probability of failure is calculated very idealistically.

In accordance with present situation, it is a dire now to incorporate human reliability analysis along with structural reliability analysis as different industries are discussed are acquired. Few of them are reserved for specific industries but some of them have the provision to tailor/modify according to the requirement. Among different techniques author's choice is to recommend the model of HEART for Human Reliability Assessment. The reason of selecting this model of HEART is transparent, as this model has also been tailored before by Air Traffic Management and Railways. In other words it works well or it has the flexibility to adjust with any other industry.

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Note: Provide figure 2