A BRIEF REVIEW ON METHODOLOGY & TECHNIQUES IN HUMAN RELIABILITY ASSESSMENT.

Rudy Wawolumaja

Abstract

Modern technology has devised mankind with methods and tools to do things much more powerful than before . Together with the benefit, it carries along more risk of unintentional destruction. Three Miles Island, Chernobyl and Bhopal accidents are obvious examples of accidents in man made systems. Human error in those accidents is considered as one of many factors responsible for the accidents. The importance of human aspect in man made systems, especially in high risk systems such as nuclear plants, offshore rigs etc. has been increasingly recognised. Therefore effort and study of human role in the overall reliability of engineering systems or human made system leads to Human Reliability Assessment (HRA).
This paper briefly discussed : Human Reliability Assessment within Risk Assessment. as the framework where human error study in the context of large system fits in. Then the discussion will be on the human error data collection methodology & techniques.

Part 1. Probabilistic Safety Assessment.

Human Reliability Assessment (HRA) is more beneficial to be studied and understood in relation with broader area of Risk Assessment. In this broader area of risk assessment process or the so called Probabilistic Safety Assessment (PSA), HRA fits in the slot of the human aspect of the overall risk assessment process.

The process of PSA itself is as following :

Phase 1. Hazard Identification.

-Identification of hazard is to be done in the earliest stage of the system life cycle, that is in the conceptual and preliminary design stage. In this area HAZOP (Hazard and Operability Study) techniques & FMEA is usually utilised simultaneously.

-Identification of hazard during and after detailed design stage usually utilises ‘Fault Tree Analysis’ and ‘Event Tree Analysis’.

Phase 2. Quantification of Hazard.

Once hazards have been identified, it needs to be quantified. Quantification provides the ability to measure, to compare the level of risk. Level of risk is defined as probability of an event times its consequence.

Phase 3. The estimate risk is then compared with the risk criteria.

If the estimate risk is not adequate, improvement has to be made to reduce level of the risk into acceptable level. It may be the redesigning of certain function. The PSA would re-examine the improved system, that is reiterate to phase 2. If the estimate of risk is adequate, then proceeds to phase 4.

Phase 4. Documenting.

This is necessary for the future review.

Phase 5. Quality Assurance System.

QA is to be implemented to prevent the adequacy of the system risk from deteoriating.

Part 2. Human Reliability Assessment (HRA).

HRA is a multidisciplinary subject, involving engineering and reliability as the hard approach and psychology and ergonomic as the soft approach. In the hard approach, HRA requires to quantify risk and it should fit into a mathematical model of the PSA (Probabilistic Safety Assessment). Moreover the complexity of human nature recommends HRA approach using psychology and ergonomic as the soft approach.

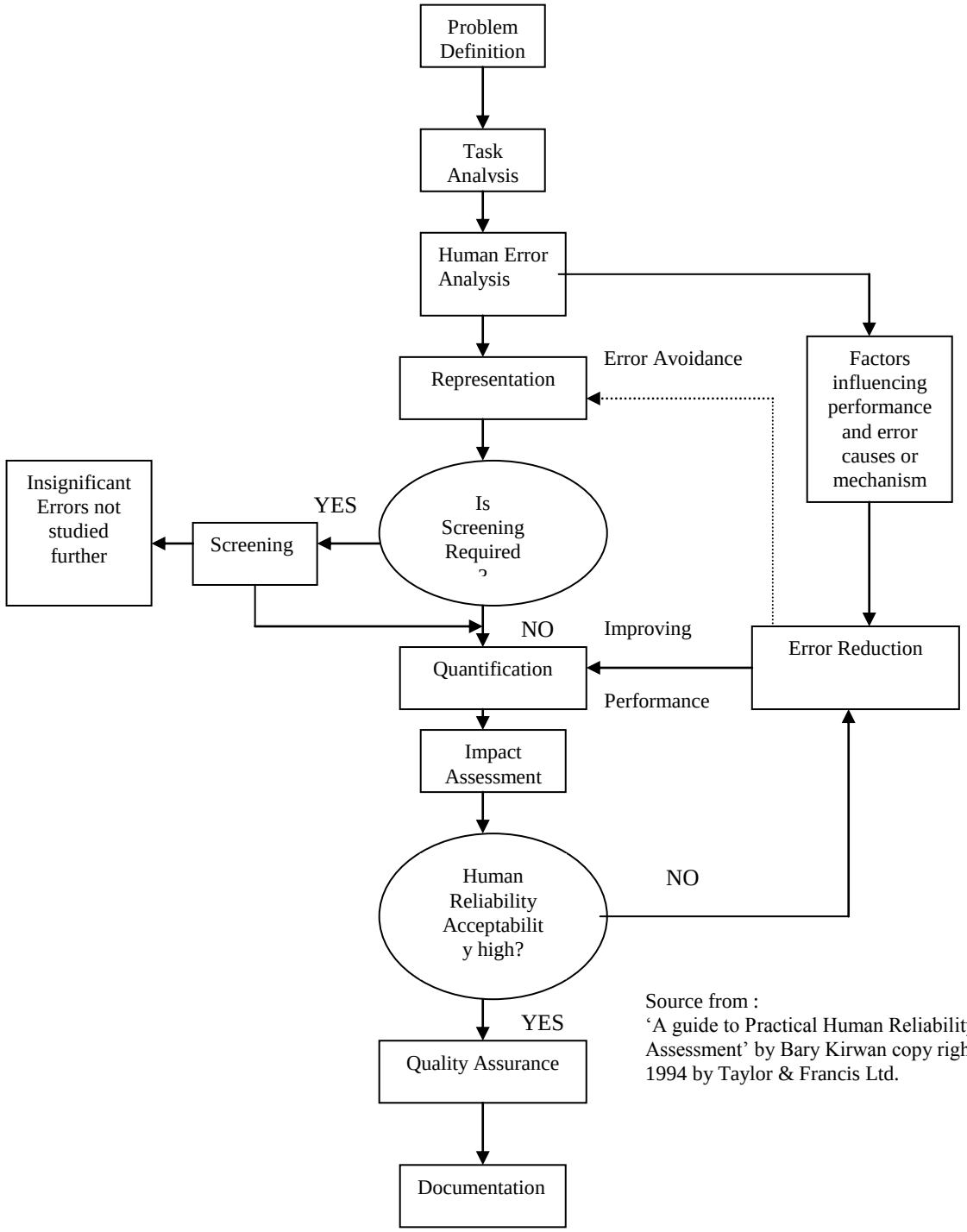
Using those hard and soft approach, there are three main objectives of HRA, i.e. :

1. Human Error Identification
2. Human Error Quantification
3. Human Error Reduction.

It can be seen they are pretty similar to the PSA process.

To achieve those objectives, Kirwan (1994) elaborate HRA into 10 generic methodology of :

1. Problem definition.
2. Task analysis.
3. Human Error Analysis.
4. Representation.
5. Screening.
6. Quantification.
7. Impact assessment.
8. Error reduction.
9. Quality Assurance.
10. Documentation.



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Phase 2-5 is the area of Human Error Identification, similar/analogous with Hazard Identification
Phase 6 is Human Error Quantification, analogous with Hazard Quantification in PSA.
Phase 7. Impact Assessment leads to the evaluation of the system adequacy compared against criteria. If the adequacy is considered not acceptable, phase 8 (Human Error reduction is to be done and the reiteration of the assessment through phase 6 is performed. If the adequacy is considered acceptable than proceeds to phase 9-10, Quality Assurance and Documentation which is very similar with the last step in PSA

2.1 Problem definition

is to answer the question of :

- What is the area of the assessment ?
- Should the assessment be quantitative or qualitative ?
- How far should the scope of an HRA go ?

There are several factors direct and constrain the HRA :

1. The system vulnerability to human error.

In a system where human have a significant role in dealing with the complexity of the system, in connecting many interactive subsystem and in compensating for the lack of flexibility of subsystem, then HRA have to be more intensive. On the other hand, if the system doesn't depend much on human reliability for safe operation or if the system is similar to other systems, which is relatively safe for many years, then detailed HRA is not necessary.

2. HRA could be part of PSA or stand alone.

In the stand alone HRA, in case of HRA aims are done with purpose of improving plant performance, then a formal error quantification may not be necessary, qualitative approach may be more beneficial. On the contrary, if HRA is carried out as part of PSA then quantification is compulsory.

3. System design life cycle.

System design life cycle consists of several sequential phases, i.e. : conceptual phase, preliminary engineering phase, detailed design, commissioning, operation & maintenance phase and finally decommissioning phase. The system life cycle phase will constrain the HRA, especially in the phase prior to the detailed design phase. On conceptual and preliminary engineering phase, HRA assesses only major hazard, using HAZOP, screening HRA. In the detailed design phase and after, there will be more information available, therefore more detailed HRA is feasible to be carried out in these phases.

2 .2 . Task Analysis.

The purpose of this phase is to obtain a complete and comprehensive description of the operator task to achieve systems goal. To make it simple, this phase is to answer the question of : 'What should the human in charge of the system (operator) do ?'

There are several techniques has been developed for Task Analysis. One of the most important technique is Hierarchical Task Analysis (HTA). HTA breaks down operations hierarchical. It describes the task from its top goal to the lower operation / task. The decomposition is carried out until the lowest level, which the analyst has chosen not to take further breakdown, since further decomposition would not add useful information to the analysis process.

There are three important aspect in HTA :

1. The plan, describes what order the tasks are to be carried out.
2. The stopping rule decides when to stop decomposing the task.
3. The numbering, which is important especially in the large HTA.

The other techniques mentioned by Kirwan (1994) are :

- Tabular Task Analysis (TTA).
- Critical Incident Techniques (CIT).
- Walk Through / Talk Through (WT/TT).
- Time Line Analysis (TLA).

2 3 . Human Error Analysis.

This phase is to answer the question of : 'What can go wrong and what are the consequences ?'. Human error analysis is considered as the most critical part of HRA, if one significant error is overlooked or omitted. It will not appear in the analysis which may result the underestimate of human error on the system.

The simplest approach is to consider the possible 'external error modes' (Swain & Guttman, 1983) at each step of the procedure defined in the task analysis.

EEM (External Error Modes) is classified into : (Kirwan, 1994)

- Error of omission - act omitted (not carried out).
- Error of commission - act carried out inadequately.
  - act carried out in wrong sequence.
  - act carried out too early / late.
  - error of quality (too little / too much).
- Extraneous error : - wrong (unrequired) act performed.

Another method for human error analysis is embedded within the Systematic Human Error Reduction and Prediction Approach (SHERPA, Embrey, 1986). This human error analysis model consists of a computerised question - answer routines which identifies likely errors for each step in the task analysis. (Kirwan 1994).

The other method is Human Error HAZOP (HAZard Operability Study) or known as human HAZOP, which is derived from the Hazard and Operability Analysis (Kletz,1974) tradition. One important advantage of using HAZOP in the area of human error identification is that the technique is applied at the early system design cycle, therefore human factors can be considered in the most cost effective way.

2 4 : Representation.

In this phase, the human error which is identified as having significant contribution to risk is integrated with the other factors of hardware, software and environmental in a logical and quantifiable format. This allows the overall level of risk to the system to be calculated and enables the risk assessor and managers to get clear picture of the contribution of each factor.

The basic and most often used format for representation in PSA are :

- Fault Tree and
- Event Tree.

Another methods mentioned by Kirwan (1994) are :

- Dependence (THERP) methods.
- Human Performance Limiting Values (HPLV).

2 5. Screening.

When a large number of errors has been identified, they have to be quantified. A screening analysis as the name suggests, identifies where the major effort of quantification should be directed and ignore the tasks which make little contribution to the level of risk, even if there are error there. There are several screening methods available, The Systematic Human Action Reliability Procedure (SHARP, Spurgin et al 1987) offers at least 3 methods of screening. BS5760 (1994), proposed 2 approaches for screening : gross screening and fine screening method. In gross screening, each HEP is given value of 1.0 and the effect on the system risk is calculated. Some errors will have significant effect on the system risk, the other that have negligible effect will be screened out. In fine screening, the procedure is the similar as gross screening, but HEP is assigned with a value from a

generic human error probabilities table instead of assigning the value of 1.

2 6 : Human Error Quantification .

Once the human error has been identified, human error is to be quantified. The most common measure of human reliability is the Human Error Probability.

BS 5760 (1994) defined HEP as :

$$HEP = \frac{\text{number of error occurred}}{\text{number of opportunity for error}}$$

For the purpose of human reliability quantification, there are several HRQ techniques has been developed.
Kirwan (1994) stated, that there are seven techniques currently reviewed by a UK peer group. i.e. :

1. Absolute Probability Judgement (APJ).
2. Paired Comparison (PC).
3. Techniques for Human Error Rate Prediction (THERP).
4. Human Error Assessment and Reduction Techniques (HEART).
5. Influence Diagram Approach (IDA)
6. Success Likelihood Index Method (SLIM).
7. Human Cognitive Reliability Method (HCR).

Some of those techniques are based on using expert judgement techniques such as SLIM & APJ, meanwhile THERP & HEART use a mixture of partly data & expert judgement approach.
Historically these techniques emerged after the unsuccessful attempt to develop human error data banks.

Other than those 7 techniques reviewed by a UK peer group, Kirwan (1994) identifies other techniques such as :

- Accident Sequence Evaluation Programmes (ASEP).
- Socio Technical Approach to Human Reliability Assessment (STAHR).
- Human Reliability Management System (HRMS).
- Justification of Human Error Data Information (JHEDI).
- Maintenance Personnel Performance Simulation (MAPPS).
- System Analysis of Integrated Networks of Tasks (SAINT)

MAPP and SAINT are simulation approach.

2.7. Impact Assessment.

Human Error quantification is to answer the questions of : ‘ Is the system acceptably safe ?
if not, how to reduce the risk to acceptable level ?’

Human Error Quantification output is HEPs values and as they are assigned to the various events in the fault or event tree, the TOP event (Total Loss of Output) can be derived. The final result of the system risk or reliability is then compared against predefined criteria, which is used to answer those two questions above.

If the result is acceptable safe, then phase is proceeded to the Quality Assurance & Documentation phase. On the contrary, if the result shows unacceptable safe or violates criteria, then PSA must decide which events gives the most contribution to the high level of risk. The culprit of high impact events or event sequences must be reduced which is the area of Human Error Reduction.

2.8. Error Reduction.

In this area , ergonomic plays the most important role. Kirwan (1990) mentions several ways of reducing the critical impact of human errors on the system , they are :
“*Prevention by hardware and software changes* : Use interlock devices to prevent error; automate the task etc.
Increase system tolerance : make the system hardware and software more flexible or self correcting to allow a greater variability in operator inputs which will achieve the intended goal.
Enhance error recovery : enhance detection and correction of errors by means of increased feedback, checking procedures, supervision and automatic monitoring of performance.
Error reduction at source : reduction of errors by improved procedures, training, and interface or equipment design.....”

Kirwan (1994) proposed several methods in error reduction analysis : “.....

1. The use of task analysis to identify & reduce errors (tabular task analysis).
2. The use of Human Error Identification methods (e.g. SHERPA or human HAZOP approach) to identify errors and derive error reduction approaches.
3. The use of PSA sensitivity analysis methods to identify ‘sensitive’ errors which can be targeted for error reduction.
4. The use of quantification methods with built in error reduction strategies in HEART.

5. The use of quantification methods with sensitivity analysis capabilities in SLIM, HEART & HMS.
6. The use of quantification with error reduction analysis capabilities in HRMS.

.....”

2.9. Quality Assurance.

Quality Assurance means, firstly the assurance that a quality HRA has been carried out appropriately. The HRA & PSA should be periodically repeated during the whole life time of the system. Secondly, the error reduction assumptions relating to improvement of human reliability are guaranteed, it is to assure that all the error reduction mechanism is effectively implemented in the system.

2.10. Documentation.

This phase is a very important phase and must fulfil the three following requirements : (Kirwan, 1994)

1. All assumptions and results made during the assessment should be documented.
2. The Human Reliability Assessment (HRA) should be auditable by and understandable to an independent assessor.
3. The HRA should be repeatable.

Part 3. Human Data Error Collection.

3.1. The Need for Data :

Kirwan (1995) stated that all those techniques of APJ, PC, THERP, HEART, IDA, SLIM, HCR would benefit from the availability of human error data in one or more of the following ways :

* Data could be used for validating the techniques.
* Data would be useful for the calibration of techniques, such as PC and SLIM.
* Data could be used for incorporation into a techniques database, e.g. THERP, HCR and HEART.

Other than that, the need for data collection are :

1. For PSA / HRA analysis purpose, that is to provide numerical data.

2. For plant safety improvement, by identifying human error problems and introducing measures to reduce / prevent errors that are related to safety.
3. For plant performance improvement other than safety by identifying human error problems and introducing measures to reduce / prevent error that are related to plant performance.

3.2. Classification of Data .

Kirwan (1994) classified human error data into two major types, first qualitative data and second quantitative data.

* Qualitative data, can be used for either error reduction strategies, based on human factors experimentation or for specific error reduction guidelines based on feedback from operational experience.
* Quantitative data can be in the form of relative data or absolute data. Relative data gives the idea of higher or lower than, that is probability of A is higher or lower than probability of B, meanwhile absolute data gives the exact number of HEP, or the probability is 0.5. For PSA usually the absolute data is required.HEP estimates is used in the validation of HRQ techniques as mentioned before or it can be directly used for the quantification in PSA if enough data are available.

Another point of view, HEPs data can be classified into :

- real operating experience data.
- simulator data.
- experimental (performance literature) data.
- expert judgement.
- synthetic data (i.e. data derived from HRQ techniques).

3.3. Type of Human Error Data.

1. Human Error data bases.

There has been several efforts done to establish human error database. It can be trace back to the 60 & 70 decades (Kirwan, 1994), the efforts of :

- American Institute for Research's data base of human error probabilities, which is proved by Swain in 1967 to be invalid mathematically.
- The Sandia human error bank (SHERB).

- The Operational Recording & Data System (OPREDS).
- Bunker Ramo Tables.
- Techniques for estimating personnel performance standards (TEPPS).

During this decade of HRA, the attempt is on creating human error data bank, to follow the success on data bank creation for hardware components. However the attempt to develop human error data banks are considered to be not successful as in case of hardware components.

Based on the understanding of past problems and data base limitation, there are extensive efforts to develop better data base for human error data. A research project has been set up at Birmingham University for developing a usable, accurate and validated human error data bank, called CORED-DATA, which is sponsored by HSE. Those package will be publicly available in 1997. Right now there have been 250 Human Error Probabilities compiled, as the target of 300 HEPs achieved, CORE-DATA will be released. CORE_DATA applies in nuclear, chemical, offshore and transport industry.

2. Judgmental task data.

In the case of empirical data on tasks and task performances are not available, expert estimates of reliability can be used. The techniques which is usually used are SLIM or APJ as mentioned in section 2.6. To estimate HEPs, those techniques utilise expert's knowledge and experience.

3. Human factors / engineering data base (Cox, 1991).

Advisory Group for Aerospace Research and Development (AGARD) has published an extensive and comprehensive engineering Data Compendium, Human Perception and Performance. This compendium was designed to equip engineers and designers with human factors data in designing reliable data. It contents comprehensive information on capabilities and limitation of the human operator, with special emphasis on those variables which affect the operator's ability to acquire, process and make use of task-critical information.

4. Accident and Incident Data. (Cox, 1991).

At least there are two institution provide data base of case histories of accidents with hazardous materials which happened world-wide over the last 30 years in the various industrial activities of

processing, storage, trans-shipment, transport and application. The data base are :

- FACTS provided by TNO Division of Technology for Society.
- MHIDAS provided by Safety and Reliability Directorate.

3.4. Problems of Data Collection.

There are at least two problems identified by Kirwan (1994), related to the qualitative data collection, they are :

1. Reluctance to report, due to the sanction or consequences may occur to the reporter if the events are reported. To overcome this problem, the error reporting scheme should be based on no blame or an anonymous approaches.
2. Successful data collection scheme needs specific dedicated individuals who are responsible for investigating incidents and collecting error data. Most of the company management are reluctant to apply such dedicated personnel.

Kirwan (1994) identifies problem related to the collection of quantitative data or HEP data as following :

1. Incomplete data base due to data of human errors are not reported. Human errors which do not lead to the non compliance to the plant's technical specification are can be used unlikely to be reported. Human errors which are recovered almost immediately are unlikely to be reported.
2. Insufficient number of events may create insufficient information, small number of events will generate low value of HEP, because the numerator of HEP (number of errors) will be low.
3. Information of the 'root causes' of events are seldom incorporated into error reporting scheme.

All those problems may create degree of uncertainties of the HEP accuracy.

Conclusion :

This paper outlined very briefly the HRA framework as an introduction; some techniques are mentioned and inventoried.

- HRA are used for assessing and reducing risk for the safety of a system or it can be used also for improving the performance of the plant for the purpose other than safety.
- There are sufficient techniques available in HRA and there are still more techniques and tools being developed.

- Despite of its limitation, HRA has practical useful value.
- The HRA approach requires special training and education, to develop skill and judgement for individual assessor.

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