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Human and Organizational Factor Risk Assessment in Process Industry and a Risk Assessment Methodology (MEDIA) to Incorporate Human and Organizational Factors

Mehmood Ahmad*[a], Marco Pontiggia[a], Micaela Demichela[b]

[a]D'Appolonia S.p.A. Milan, Italy
[b]Politecnico di Torino, Torino, Italy
mehmood.ahmad@dappolonia.it

Human and organizational factors (HOF) contribute to large number of accidents in process industries, therefore it is of prime importance to include HOF into risk assessment. In this paper, a newly developed methodology "Method for Error Deduction and Incident Analysis (MEDIA)" is presented. MEDIA is a taxonomy based HOF assessment methodology which can be used to quantify the HOF risk based on an accidental database (EMARS). Primarily, MEDIA analyzes different organizational characteristics and their effect on human action's outcome. This methodology also accounts for available risk reduction factors and critically of human action failure.

1. Introduction

It has been reported in the literature that HOF are the root causes to large number of industrial accidents. Nivolianitou et al. (2006) has stated that about 19% of industrial accidents caused solely by human failures and with the inclusion of equipment failure, the share of HOF increased to 40%. Quantitative Risk Assessment (QRA) is a widely used risk assessment methodology in process plants. After analysing 15 QRAs which had applied to offshore facilities in Norwegian shelf, Skogdalen and Vinnem (2011) had concluded that QRAs differ increasingly to the extent to which they include HOF and also none of them describe how HOF should incorporate in overall risk management. Although, Norway's and UK's legislations require that HOF should be included into QRA study. Gambetti et al. (2012) emphasis on the understanding of human factors and also on the practical tools required to perform human factor studies.
Since QRA parts count method extensively apply in process industries for risk assessment, therefore as a case study MEDIA is used along with QRA to estimate the HOF risk.

2. Existing safety approach in process industry

This section describes the major concepts use in process design, organizational and human factor assessment.

2.1 Supporting theories in process design

In process industries, the control system is designed as a layer of protections used for risk reduction as illustrated in Figure 1 (Standard International,1999, p. 52). In case, process deviates from its design intentions due to any human error or equipment malfunctioning, the purpose of subsequent safety layer is to bring system back under design specifications. Therefore, there might be some errors during operations but due to subsequent safety layers these errors cannot lead to an undesirable situation until subsequent safety layers fail to intervene due to any given reason.
Meanwhile, it is also important to include HOF analysis throughout the project's lifecycle and also requires to determine which situation (e.g. normal, abnormal or emergency) is considered for HOF assessment. It is also suggested by Kirwan (1998 b) to determine the targeted operational situation in Error and Recovery Assessment (HERA) framework and is reported in Stanton et al. (2005, p. 193).

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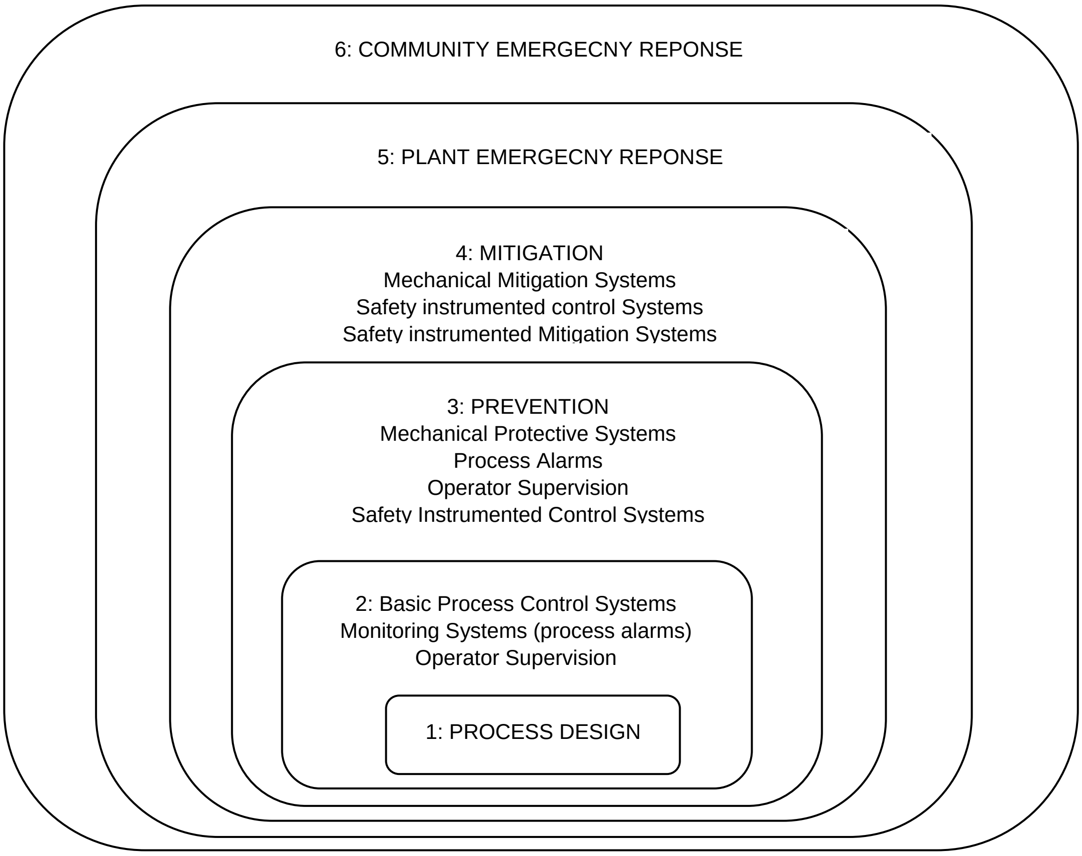

Figure 1: Typical risk reduction methods in process plants

OGP (2011) identified five stages of project's lifecycle and associated Human Factor Engineering (HFE) activities at each stage as illustrated in Table 1.

Table 1: Project's lifecycle and associated HFE actions

Project's life cycle stage	HFE actions
Concept	HFE screening
FEED	HF design analysis
Detailed engineering	Design validation
Commissioning	Pre start-up review
12 months after start-up	Operational feedback

2.2 Organizational structure

It is reported by Daniellou et al. (2011) that organizational characteristics can influence the risk of industrial accidents in either way. Meanwhile, it is quite obvious that humans itself inherent a tendency to make errors even in an ideal working condition. Therefore, human errors are inevitable but can be reduced by improving organizational characteristics.

It is of vital importance to know the organizational structure in order to evaluate the organizational factors and to include them into risk assessment. Daniellou et al. (2011) categorized organizational structures into three main classes depending on flow of information and hierarchy. In this study a vertical organizational structure has been considered as illustrated in Figure 2. In order to perform simultaneous HOF assessment, a division between an organization and an operator (human) is also necessary to assign clear responsibilities to each party and then to evaluate these assigned responsibilities. Figure 2 describes an organization and operator (human factor) division used in MEDIA analysis. For simplicity it is assumed that a plant requires two operators for its operations: console and a field operator. Supervisor is also considered in operator (human factor) category.

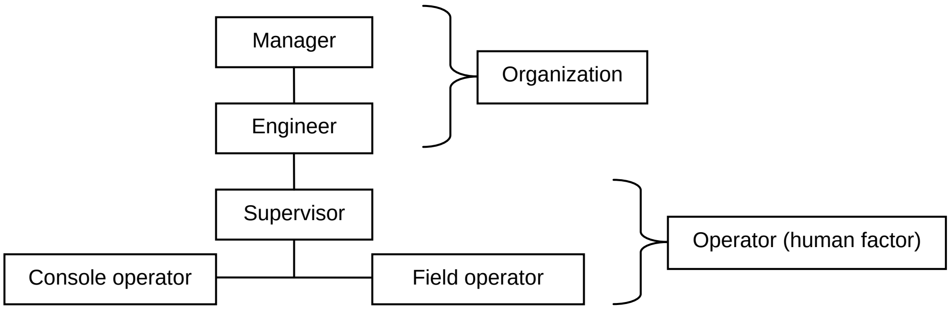

Figure 2: Assumed organizational structure

2.3 Existing HOF assessment methods

There are several methods for HOF assessment, some of them were developed especially for the process industries. For instance, System for Predictive Error Analysis and Reduction (SPEAR) developed by Centre for Chemical Process Safety (CCPS) and is reported by Stanton et al. (2012, p. 218). SPEAR is a qualitative taxonomy based approach to identify human actions into one the five behaviour types based on subjective judgment as illustrated in Table 2 (Stanton et al., 2005).

Table 2: SPEAR behavioural error taxonomy

Action
Retrieval
Check
Selection
Transmission

There are some other methods developed to improve the organizational factors in process industries: Organizational Risk Influence Model (ORIM) method was developed by Øien (2001) with an intention to assess and quantify the organizational risk indicators. Barrier and Operational Risk Analysis (BORA) developed as a result of BORA project. BORA provides an analysis about the performance of safety barriers, which apply to prevent the hydrocarbon release and thus by inclusion of safety barrier performance, hydrocarbon leak frequencies can be updated (Aven et al., 2006).

But these methods lack of information how to integrate both organizational and human factors into one Model. Since organizational factors play an important role to shape the attitude of its employees in either way (i.e. safe or unsafe). Therefore, MEDIA is developed to include the both organizational and human factors into one model.

3. Method for Error Deduction and Incident Analysis (MEDIA): a new approach

MEDIA is a taxonomy based HOF assessment method. Figure 3 illustrates the fundamental theory behind MEDIA. MEDIA assumes that process plants consists of three main elements:- Operator, Equipment and Organization. Equipment and organization provides a context (environment) for operator to perform actions. Any change in equipment (reliability) or organization (factor) effects the outcome of human actions. At the same time, operator (human) inherit a tendency to make errors even in an ideal working condition.

The consequent effect of inevitable operator (human) errors is mitigated due to subsequent safety layers, as described in Figure 1. These errors called “safe errors” as demonstrated in Figure 3. After incorporating risk reduction by safety function, MEDIA can provide the net HOF risk. This concept of risk reduction is used to avoid the over estimation of human factor contribution to overall risk. At the same time, organization and operator (human) are also recommended to use as an independent safety layer as this concept is called “Manual Safety Functions” in Figure 3.

3.1 Human and organizational factor taxonomy

After analyzing the existing taxonomy based methodologies, a new taxonomy is developed for HOF analysis that can include major risk influencing factors into assessment. Table 4 illustrates the Organizational Factor (OF) taxonomy, in which major organizational factors are listed that can have an influence on human factors.

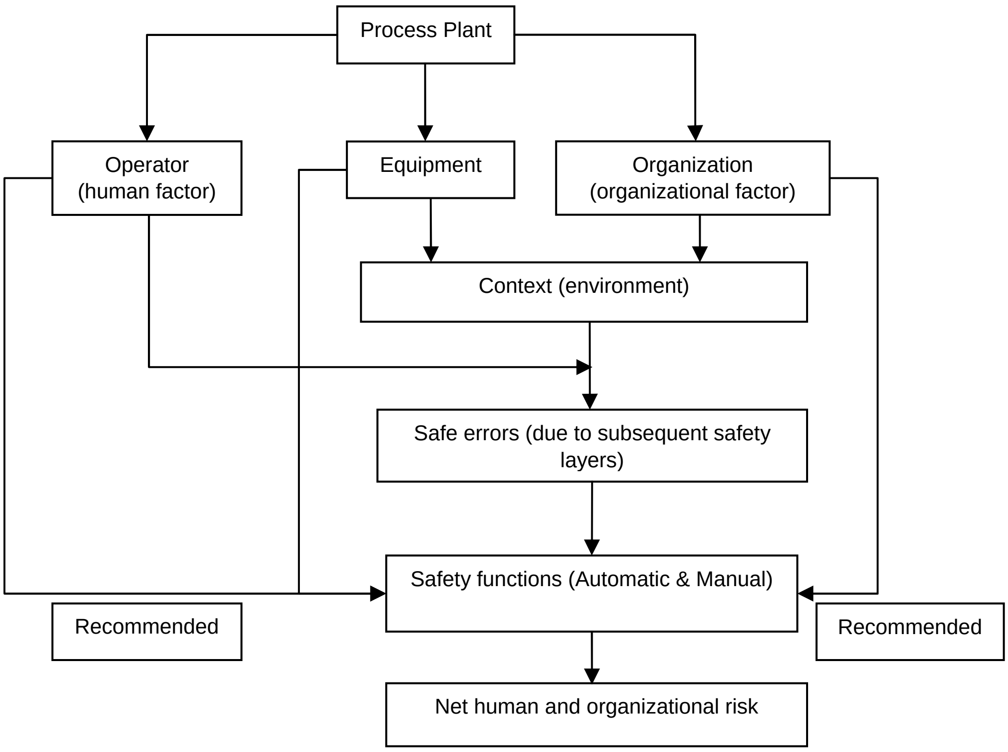

Figure 3: Method for Error Deduction and Incident Analysis (MEDIA) framework

In order to assess and quantify the OF in an industry, checklist reviews are proposed. Checklist reviews are to assess each of the five organizational factors and to assign them a probability value among two states (i.e. good or bad). The higher the probability of state "bad" of an organizational factor, the more chances that the dependant human actions can produce a -ve outcome.
Table 3 shows the Human factor (HF) taxonomy, Significance of this HF taxonomy is that this is an action based taxonomy rather than an error based taxonomy. Critical human actions/ interventions can be identify using P&IDs and guided brainstorming. Meanwhile, human interventions are also analyzed for associated safety layers described in Figure 1 and adjusted accordingly. Since human interventions became more critical as they move from safety layer 2 to safety layer 4 or higher.

Table 3: MEDIA Human Factor (HF) taxonomy

Monitoring (M)
Control room actions (A)
Communication (C)
Manual on field actions (F)
Reporting (R)

Table 4: MEDIA Organizational Factor (OF) taxonomy

Training (T_o)
Design (D_o)
Procedures (P_o)
Company's management (M_o)
Safety culture (C_o)

"Reporting" is also included in Table 3 although "Reporting" itself does not lead to significance process deviation but with combination of other process malfunctions it can lead to an unpleasant situation. Furthermore, "Reporting" is an important factor to avoid near misses in an industry.
In order to show the effect of OF on HF, linkages between organizational and human factors are developed and simulated by using Bayesian networks (BN).
BN can be developed by using HUGIN Expert or MSBNx software. In this paper HUGIN Lite 7.7 has been used for BN.

3.2 Bayesian network

BN technique is used in MEDIA to determine the dependencies between organizational and human factors and also to quantify the effect of organizational factors on human factors.

$$P\,(A|B) = \frac{P\,(B|A)\,.\,P\,(A)}{P\,(B)} \quad (1)$$

Eq(1) describes the Bayes' theorem developed by Thomas Bayes in 18th century. The term on left hand side "$P\,(A|B)$" is known as posterior probability, while term "$P\,(A)$" is the prior probability of an event A and "$P\,(B|A)$" is the conditional probability of event B given event A. "$P(B)$" is the probability of event B. Figure 4 illustrates the MEDIA network approach to link the organizational and human factors. Currently, It is assumed that all the five identified organizational factors have an influence on each of the human actions as shown in Figure 4. In Figure 4, random probability values have been used for each of the two states of an organizational factor and also for the conditional probability of failure of HF given organizational bad state. Dependencies and probabilities will be modified after analyzing past accidents in order to get more realistic effect of organizational factors on human factors.

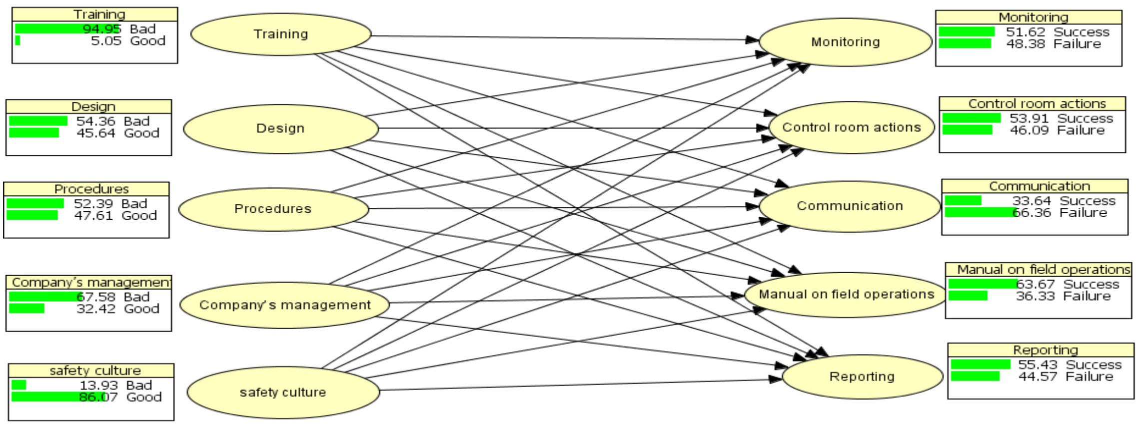

Figure 4: MEDIA Bayesian network approach

After simulating the network by Bayesian approach the probability of success/failure of each of the human actions is obtained with the inclusion of an influencing factor (e.g. organization).
Eq(2) is used to quantify the risk due to HOF. For example "Monitoring" activities can be quantify using Eq(2) in following way:-

$$\text{Risk HOF}\,(\text{Monitoring}) = E \cdot e^{P\cdot \ln(X/E)} \cdot \left(\sum_{i=1}^{4} (N\,I\,Si \cdot i) \cdot R\right) \quad (2)$$

While
E = Inherit human errors during (Monitoring) actions (i.e. 4.73E-04/y from analysis of past accidents)
P = Probability of human action failure given organizational characteristics, $0 \leq P \leq 1$, (i.e. 0.48 in Figure 4)
X = Total number of human errors during (Monitoring) action (i.e. 7.09E-04 ev/plant/y from analysis of past accidents)
i = No. of safety layer associated to human actions (Monitoring)
$N\,I\,Si$ = Number of human action associated to i^{th} safety layer
R = Probability of failure of human (Monitoring) actions (i.e. 0.0212 from analysis of past accidents)
Eq(2) is used for each of the five mentioned HFs to provide the total risk due to HOF.
MEDIA model can be used in two possible ways:- if an industry provide states of organizational factors identified in Table 4, relevant HOF risk can be calculated. In contrary, MEDIA can evaluate different organizational characteristics and can compare HOF risks associated with each of these organizational structures to recommend the most suitable solution for an industry.

4. Integration of MEDIA with the Quantitative Risk Assessment (QRA)

QRA has been selected as a case study in order to integrate the HOF assessment with conventional risk assessment. This integration can benefit the overall risk calculations and also during the preventive measures. In QRA parts count method, plant is divided into isolatable sections. One isolatable section has

been selected for MEDIA application consists of a scraper launching trap, pressure indicators, Pressure Safety Valve (PSV) and instrumented activated Emergency Shut Down (ESD) valve. In this assessment only normal operating condition and only "Monitoring" human activities have been considered. It is assumed that different organizational levels as illustrated in Figure 2 are independent from each others. Total number of critical "Monitoring" activities in this isolatable section are 3 based on expert's judgment, of which 2 belong to 4^{th} safety layer and 1 belongs to 2^{nd} safety layer as per P&IDs. Now, using eq(2) potential risk from HOF is calculated as illustrated in Table 5. ESD valve is an automated safety function with risk reduction factor equal to 100-1000 for low demand operations. Table 5 presents the net HOF risk by taking into consideration organizational characteristics, possible failure of human interventions and also the risk reduction factor.
In similar way other isolatable sections can also be analysed for HOF risk and if risk is higher than certain level then preventive measures shall be recommended.

Table 5: Integration of HOF with QRA

Risk HOF (ev/y) Eq(2)	Risk reduction factor (SIL-2)	Net HOF risk (Monitoring)
1.22E-04	100-1000 (ESD)	1.22E-07

5. Discussion and conclusions

A new methodology (MEDIA) has been proposed for HOF risk assessment and its potential application along with QRA. Main challenge during the HOF assessment (especially when it is outsourced) is the amount of information a company can provide about their organizational structure and also about human interventions. Therefore, a past accidental database has been used and methodology developed in a way to provide good estimations with fewer possible required information. A checklist survey with a company is highly recommend to understand and quantify the organizational factors and then to correlate them with the human action's outcome. Other main challenge of MEDIA application is that HOF assessment is based on an accidental database (under development) and conclusions from accidental scenarios are highly subjective. Therefore, multiple experts will be used for accidental analysis in order to provide more realistic quantification of HOF.

References

API (American Petroleum Institute) 581, 2000, Risk-Based Inspection Base Resource Document, First Edition.

Aven T., Sklet S. and Vinnem J.E., 2006, Barrier and operational risk analysis of hydrocarbon releases (BORA – Release): Part 1. Method description, Journal of Hazardous Materials, 137, 681-691.

Daniellou F., Simard M. and Boissières I., 2011, Human and organizational factors of safety: a state of the art, Institute for an Industrial Safety Culture, Toulouse, France, http://www.FonCSI.org/cahiers/, accessed 11.09.2013.

EMARS (Major Accident Reporting System), Major Accident Hazards Bureau, European Commission, https://emars.jrc.ec.europa.eu/?id=4, accessed 20.10.2013.

Gambetti F., Casalli A. and Chisari V., 2012, The human factor in process safety management, Chemical Engineering Transactions, 26, 279-284 DOI:10.3303/CET1226047.

Nivolianitou Z., Konstandinidou M. and Michalis C., 2006, Statistical analysis of major accidents in petrochemical industry notified to the major accident reporting system (MARS), Journal of Hazardous Materials,137, 1-7.

OGP (International Association of Oil and Gas Producers), 2011, Human factor engineering in projects, Report no. 454, London, United Kingdom, http://www.ogp.org.uk/publications, accessed 19.05.2013.

OREDA (Offshore Reliability Data Handbook), 2009, Volume 1- Topside Equipment, SINTEF, Norway.

Ølen k., 2001, A framework for the establishment of organizational risk indicators, Reliability Engineering and System Safety, 74, 147-167.

Skogdalen J. E. and Vinnem J.E., 2011, Quantitative risk analysis offshore - Human and organizational factors, Reliability Engineering and System Safety, 96, 468-479.

Standard International 1999, International Electrotechnical Commission IEC 61511-1: Functional safety: Safety instrumented systems for the process industry sector.

Stanton N.A., Salmon P.M., Walker G.H., Baber C. and Jenkins D.P., 2005, Human factors methods: a practical guide for engineering and design, Ashgate Publishing Group, Oxon, GBR.