Consideration of Human Errors in Risk Management

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Abstract: This essay gives an overview about the conception of human failures in risk assessment methods. Starting with a short definition of risk and risk management, it presents elements of human behaviours. Systematic analyses such as Human Reliability Analysis, Incident Risk Management or Human FMEA allow assessing risks linked by human handling. At the end, this text proposes measures to avoid, or at least reduce, the assessed risks.

Keywords: *human errors, risk management, human-machine systems, human risk assessment, Human Reliability Analysis (HRA), Incident Risk Management (IRM), Human Failure Mode and Effect Analysis (Human-FMEA)*

1. Introduction

The risk analysis and management process has taken nowadays a fundamental importance. Because of the market pressure, norms certifications and always higher consumer expectations, companies can't avoid a substantial assessment of the risks within their processes. This essay focuses on the consideration of human factors in a risk analysis. After defining the concept of risk analysis, we will shortly introduce the concept of human-machine-systems and the influences a human is exposed to during his working time. The main part of the thesis consists in the presentation of risk assessments and reduction methods.

2. Definition of risk and risk management

Risk management is the process of measuring, or assessing risk and then developing strategies to manage the risk. The strategies employed include transferring the risk to another party, avoiding the risk, reducing the negative effect of the risk, and accepting some or all of the consequences of a particular risk. Traditional risk management focuses on risks stemming from physical or legal causes. It doesn't matter the type of risk management, all large companies have risk management teams.

At first it is important to give a definition of a risk. They are many different ways of defining risks, depending on which business area is considered. Two possible general definitions of risk are the following:

- A risk is a chance or possibility of danger, loss, injury, or other adverse consequences[1]
- Risk is the possibility of suffering loss or injury[2]

We also want to say that risk and opportunity usually go hand in hand. Every project strives to reach something innovative that hasn't been done before. The opportunity for advancement can't be achieved without taking risks. The next quotation illustrates well the concept of risk vs. opportunity and the aim of continuous risk management:

"Risk in itself is not bad; risk is essential to progress, and failure is often a key part of learning. But we must learn to balance the possible negative consequences of risk against the potential benefits of its associated opportunity."[3]

In ideal risk management, a prioritization process is followed, whereby the risks with the greatest loss and the greatest probability of occurring are handled first, and risks with lower probability of occurrence and lower loss are handled later. In practice the process can be very difficult, and balancing between risks with a high probability of occurrence but lower loss vs. a risk with high loss but lower probability of occurrence can often be mishandled.

Risk management also faces a difficulty in allocating resources properly. This is the idea of opportunity cost. Resources spent on risk management could be instead spent on more profitable activities. Again, ideal risk management spends the least amount of resources in the process while reducing the negative effects of risks as much as possible.

They are many commonly used risk assessment methods. We don't want to enter into details at that stage, but we will present three of them in chapter 5, which focus on the human factors in the risk analysis. Nevertheless we provide a list in the next table with some criteria for choosing the right risk assessment method[4].

Cost	Cost of employing, as well as for purchasing and implementing a method
External influences	Approval of external parties needed? (government, auditors or others)
Agreement	Management and security analysts agreement to the

[1] Concise Oxford Dictionary, ninth edition
[2] Merriam-Webster Online Dictionnary
[3] From [VScoy92]
[4] From [Licht96]

	selected method
Organisational structure	Use fast and inexpensive, or traditional, time-consuming and well-documented method?
Adaptability	Ability to adapt to an organisation's needs
Complexity	Complexity should be limited and adapted to the practical needs
Completeness	Method has to consider all aspects of the system
Level of risk	The level of risk assessed in the company influences the choice of the method
Consistency	This considers the reliability of the results
Usability	The method should be understandable by all the analysts, but also by the management
Feasibility	Feasible in terms of availability, practicality and scope
Validity	The method should produce valid results
Credibility	Result must be accepted by analysts and management
Automation	Automated method are faster, however human intuition and creativity get lost

3. Human-machine systems

It is not possible to separate the human from the technology factors. The user needs to control the machine in order to make the process work. We give an example to illustrate this assertion. When flying an aeroplane, the pilot uses the steering stick to control the pitch and roll axes of the plane, and the rudder pedals to control the yaw axe. The airplane speed can be controlled by the throttle and mixture, which define the power of the motor. The pilot perceives the position of the vehicle by looking through the windscreen or with the help of the artificial horizon. The exact speed of the plane can be monitored on the airspeed gauge, the altitude on the altimeter indicator. GPS equipment, gyrocompass, and radio-navigation instruments give very useful information to the pilot in order to know his geographical position. The user interface of the airplane is composed of input (steering stick, rudder pedals, throttle...) and output instruments (motor monitoring gauges, altimeter, airspeed indicator, compass, artificial horizon…).

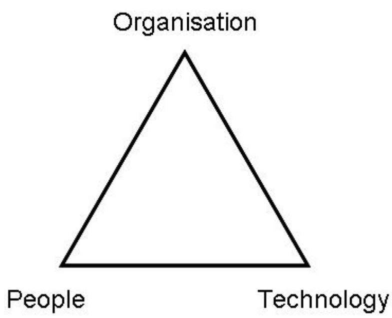

Figure 1: People-Organisation-Technology triangle

In the assessment of risks, the three components of the triangle above should be considered. People, organisation and technology have to be viewed as a whole, not as three independent part of the risk analysis. They are plenty of interactions between the three concepts.

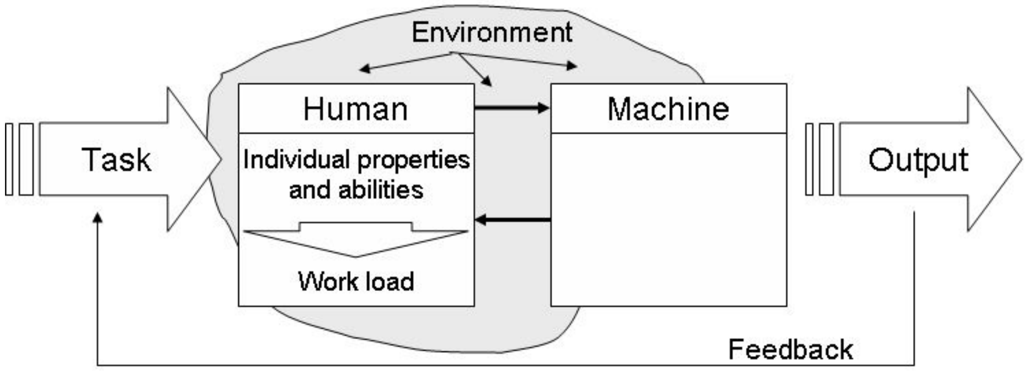

Figure 2: Interactions between human and machine in a given environment

Figure 2 shows the interaction between humans and machines. In order to have a given task done, both elements are indispensable. Besides very few craftsmen or artists, no one can pretend working without the help of machines. On the other side, machines do not have intuition and intelligence abilities. They need orders like setup, start and (emergency-) stop operations… The human worker gets feedback from the machine: control parameters, alarms and other data. Only humans can understand these machine data, work them out, analyse them and transform them to new machine inputs. Humans are not ready to live in a fully automated society. The full automated airliners that Airbus tried to develop were refused by the consumers. Who would sit in plane without pilot? We see at that point, that fully automated systems are not yet possible. Interaction between human and machine will always exist.

Both machines and humans are subject to errors and influence the quality of a product. The way risk is assessed for machines and humans is very different. Automated processes - done by machines - are exposed to few external influences, which are known and can be controlled. A machine delivers statistical data. Once the setup is made, operations can be repeated and the result will be almost always the same. Humans are not able to work with the same constancy as machines. At the end, every failure can be put down to a human mistake. To illustrate this assumption, let's consider the case of an airliner crash. The next people could bear the full responsibility:

- the pilots (direct mistake)
- the company (bad work conditions, not enough training, …)
- the mechanical staff (mistake during reparations or checks)
- the authority (certification of an airplane which is not secure for flying)
- the engineers who designed the airplane

Our society excessively tends to always search for someone to bear the responsibility of an accident or error. In that sense humans are under constant pressure and have the responsibility for the end product quality.

Psychology of women and men can only be understood individually in a given situation. The way how people think is very complex. The next chapter presents some elements related to humans and the influences they are exposed to in a working situation.

4. Characteristics of human behaviours

Understanding human behaviours is still nowadays a mystery. Psychologists develop theories and try to group individuals in categories. We think that it is not possible to group human behaviours in precise categories. Humans react differently depending on the situation they are exposed to. Only a very small part of the human brain is logical, the biggest part is totally irrational and its functioning stays nowadays without any valid explanation. Humans are subject to many influences. We divide the influences in internal and external influences. The internal influences are defined by the company's environment; the external ones come under everyone's private life. The next table lists possible influences on a worker:

Internal influences	**External influences**
- trust	- leisure time
- work atmosphere, colleagues	- family and friends
- management support	- self accomplishment
- company culture (i.e. error culture)	- Maslow's pyramid
- responsibilities	- social level
- working hours	- health
- wages	
- pressure	
- competition	
- mobbing	
- motivation	
- layout of workplace (ergonomics, noise, light, temperature, …)	
- job security	

This list is not comprehensive; we could add lots of influences. It is essential to keep in mind that all these elements act and must be considered as a whole. The management forces can affect the internal influences, since they directly depend on the structural conditions. They can't act on the external influences and have to respect the private life of their employees.

Humans are not perfect, and will never be. For that reason, workers will always be prone to make errors. Every deviation from the defined right path is considered as an error. When working with repeated operations - typically a manufacture line in a factory -, workers make in average one error every thousand operations[5]. As illustration, we consider three operations with different cycle times:

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[5] [Bubb05]

Operation	Elapsed time between two errors	# errors per 8-hours shift	# errors per day
A) cycle time = 2s	33 minutes	15	45
B) cycle time = 5s	83 minutes	6	18
C) cycle time = 10s	165 minutes	3	9

Depending on the type of produced items, these failure rates implicate big losses. This shows again that potential human failures can't be ignored in a thorough risk analysis. Causes of human failures can be various: limited resources, bad designed interface, inadequate training, lack of supervision, lapse of concentration… The next chapter describes methods for assessing risks linked to human errors.

5. Human risk assessment

In this chapter we concentrate on methods for assessing the human risk. Many risk analysis methods, especially for semi- or fully automated manufacture lines only consider potential failures caused by machines. Potential failures caused by the line workers are not looked at. As we saw in the preceding chapter, making errors is part of the human nature. Humans are indispensable for making machines work, but they are also the weakest link in the work process. We think human factors should be analysed more carefully in risk assessment processes.

An easy way to assess the human risks of a process is to perform the work situation. For example, the quality of new machines designs - in different areas like medical devices, transportation or manufacturing line -, should be estimated regarding consequences of human misuse. Using prototypes, experienced employees are asked to simulate the work process and think about potential failures. Extreme conditions can be played in a flight simulator for example. Experts' observations help to detect problems. The airplane crash described by Tanja Hancke[6] could have been avoided if the cockpit layout had been tested more carefully in the design phase. For production lines, the Human-Integrated Simulation (HIS)[7] can be used. On the one hand, the simulation allows in nearly real conditions to test the user friendliness of the design, on the other hand it permits to observe the behaviour of the workers on the line. Discovering risks in early development stages save a lot of money, regarding later adaptation cost.

The next lines present four approaches that include potential human risks in their analysis.

Human Reliability Analysis (HRA):
Human Reliability Analysis determines the probability that a person correctly performs some system-required activity in a given time. It is a procedure for identifying events where human interaction could contribute to a potential failure. These events can then be quantified with a ranking based on risk. A large number of techniques are cited in the literature; early methods include THERP (The Human Error Rate Procedure) and Data Store (a data bank of performance data on the use of common controls and displays). They are also more recent approaches that can be divided into probability models, techniques based on time-reliability relationships or human judgements, and influence diagramming techniques.

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[6] [Brandt03]
[7] [Brandt03]

THERP is probably the most well known and widely used technique. It has been modified and updated over the past decade. The technique involves the decomposition of tasks into elements and the use of binary logic diagrams in which the limbs represent decision points (correct or incorrect performance), the probability of each outcome being combined with “performance shaping factors” (type of equipment used, stress, proficiency etc.). Probability values are contained in tables and databases in which tasks are decomposed into their component parts.
THERP makes the basic assumption that human functions can be considered in the same way as other components. Functions are decomposed into task elements which can be handled separately. A further assumption is that the performance of one task has an effect on the performance of concurrent or subsequent tasks and that there are adequate databases of tasks and error probabilities.

THERP suffers from the following limitations:

- it is difficult to represent the variability of human behaviour adequately
- the technique assumes each task segment can be handled separately
- it is difficult to combine human and equipment reliability values
- it is difficult to identify inter-task dependencies
- the technique is not appropriate for continuous tasks
- the method does not determine motivation of the individual

Any decompositional approach to analysing human error (of which THERP is a well-established example) is based on reductionism principles and would therefore fail to detect failures of a systemic nature.

Incident Risk Management (IRM):
The Incident Risk Management method facilitates the learning out of committed failures. The employees have to learn not to keep their errors hidden, but to learn out of these. An error can be made once, it shouldn't be repeated twice! Moreover it prevents failures to be propagated to next working steps. IRM needs a strong error culture and commitment among the employees and the management force of the company. Mutual confidence is especially required, in order that the employees announce the failures they made. A reporting system allows the employees to communicate their errors. Once a failure has been reported, a group of people have the responsibility to work the failures out and inform all the workers about this particular failure.
The system is aware that humans also make errors by chance and unconsciously. Incident Risk Management tries to motivate the workers and not to punish them when they are doing failures. If the company's culture is compatible to this error philosophy, the daily work tasks will be done in a good atmosphere with constructive and mutual control mechanisms.

Human Failure Mode and Effect Analysis (Human-FMEA):
The Failure Mode and Effect Analysis is a preventive risk assessment method with the aim, to discover, prioritize and remove potential problems in early development stages. Applied on a whole system, a design or a production process, the FMEA reduces the development time, ensures a high product quality and saves cost by avoiding work repetition. FMEA was introduced in the sixties by NASA engineers and continually developed since. Especially the automobile, medical or aerospace industries make use of the FMEA.[8]
The traditional FMEA prioritizes risks of potential failure modes regarding three criteria: occurrence, severity and failure detection before the product reaches the consumer. However it

[8] From [Dayer06]

uses potential equipment failures as basis for the analysis, and does not allow human ones to be examined. That is the reason why we propose a modified technique, called Human-FMEA. Beside the traditional categories (failure mode, cause, consequences, control possibilities, RPN computations and improvement suggestions), the Human-FMEA considers elements which are directly related to human performances such as:

- failure (failure cause regarding the human handling)
- influences / influences forms (internal or external)
- failure form (accidental, intermittent, systematic)
- improvement actions (through technology, organisation, training or communication)

These considerations of human interferences in a process make the FMEA more reliable. It can be used, both reactively, by identifying and correcting already happened mistakes, and proactively, by examining possible faults. The proactive way offers the opportunity to examine an early analysis of the human factor, therefore a chance to prevent errors exists. To take adequate measures to improve enterprise-specific factors occurs also in this phase of action. Measures concerning staff directly are highly employee-dependent and can be traced by either preventive interviews, trainings and examinations or reactive ways.

The presented methods support continuous quality improvement techniques such as the famous Deming cycle (Plan - Do - Check - Act) or DMAIC (Define - Measure - Analyze - Improve - Control - Report) suggested by the 6σ philosophy.

6. Human Risk avoidance or reducing

Once the risks have been identified, the following step is their elimination. Zero risks don't exist. By the way if would not be interesting if errors would never happen: one can only learn and progress out of past failures. We propose to follow the next strategy:

1. Eliminate the error occurrence
2. Reduce the error occurrence
3. Eliminate error consequences
4. Reduce error consequences
5. Accept the remaining failure risk if it is balanced with the opportunities

As potential errors are for every particular occupation different, we can't give universal solutions for avoiding human caused failures. Nevertheless, we suggest executives responsible for quality to look in three main directions: ergonomic, organizational or education and training measures. If they want reliable and efficient workers, executives must support and motivate them. They should foster constructive failure culture and reciprocal trust in the company.
In order to illustrate these statements, the next table lists possible measures for reducing human failures. Three working areas are considered: aviation, medical and manufacturing processes.

Aviation (pilot)	**Medical process (i.e. surgery)**	**Manufacturing process**
- Training, refresher training	- Patient case analysis and	- Best practice documents,

	discussion	guidelines
- Use of check-lists	- Monitoring of vital parameters	- Job rotation
- Bilateral checking (pilot - co-pilot)	- Training (VR, simulation)	- Adequate working conditions
- Briefing procedures	- Team work	- Training
- Air traffic control	- Bilateral checking	- Regular breaks
- Systematic instruments scanning	- Personal selection	- Ergonomic layout of the workplace
- Qualifications, certifications		- Self check practices
- Ergonomic cockpit design		

7. Conclusion

Human errors have an important influence on the quality of production processes. Human error analysis and subsequent risk reduction are of significant concern for all type of human process tasks found in various industries. By employing a systematic approach to this analysis, human error potential can be managed, its probability reduced and risk controlled.

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