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IMPROVING THE METHODOLOGY OF INCIDENT INVESTIGATIONS - MORE EFFECTIVE PREVENTION AND IMPROVED SAFETY CULTURE

ZDOKONAĽOVANIE METODIKY VYŠETROVANIA NEHÔD - EFEKTÍVNEJŠIA PREVENCIA A ZLEPŠENÁ KULTÚRA BEZPEČNOSTI

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ABSTRACT: *Investigation of major accidents, breakdowns and other unforeseen events involving hazardous substances is one of the most important tools for the efficient and effective development of safety management systems. This should be encountered in any management system operated by businesses, either as a specification of the used standard or as a description of various guidelines. These regulations apply to accidents, major accidents, and malfunctions involving the release of hazardous substances. However, they do not refer to the investigation of events outside a normal operation that do not involve the discharge of hazardous substances. It is, therefore, necessary to investigate incidents thoroughly and logically in order to prevent the occurrence of similar incidents and to provide lessons that will develop the further safety-conscious activities of employees.*

KEYWORDS: *Incident investigation. Safety management system. Root cause analysis. Investigation of responsibilities. DMAIC model.*

INTRODUCTION

Due to their activities, hazardous industrial plants always mean some risk to their environment, as potential accidents can mean different types of hazards to human life and health. The failure of technical and technological equipment has contributed significantly to the development of serious accidents over the past decade. However, it is also important to note that even the most advanced equipment from the best manufacturers, operated by the most trained professionals, can cause errors. (Katai-Urban, Vass, 2014)

Companies dealing with hazardous substances must analyze the hazards arising from their hazardous activities. If their risk falls into the socially intolerable category, they must take risk reduction (safety-enhancing) measures. Companies must be prepared to deal with deviations from normal operation and the possible release of hazardous substances. They must have procedures in place to minimize damage and the necessary protection infrastructure. (Címer, Katai-Urban, Vass, 2015)

These companies have to be more expected to guarantee a high level of safety for their environment. Analyses by the European Commission's Community Research Centre's Office for Major Accident Hazards have shown that 85% of accidents are due to human negligence and deficiencies in the safety management system. (ORGANISATION FOR ECONOMIC COOPERATION AND DEVELOPMENT, 2008) With this information, a properly operated safety management system is an important pillar of major-accident prevention. (Vass, Halász, 2007)

Events other than normal operation can be technological events, problems, deviations that do not involve the release of hazardous substances or injuries to workers but have a technology impact that may even lead to the shutdown of a technological unit. If the problem is not dealt with immediately, it can even have a serious safety impact. Such a problem could be a change in an operating parameter (eg pressure, temperature), a blockage in a line resulting from an unexpected reaction, or the shutdown of process equipment as a result of the changed conditions. As soon as possible, operator intervention can prevent the development of a serious problem or loss of production in these cases, so in addition to the above-mentioned regulations, it is worth addressing these as well. It is not possible to prepare for the prevention of all technological events, as it is almost impossible to take into account all

possibilities when preparing a risk assessment. Practical experience confirms that, as a result of operator errors and human omissions, a large number of technological events occur outside of serious events, without the aforementioned serious consequences. This is precisely why human behavior and the issue of responsibility need to be addressed in more detail in the investigation of incidents. It must be emphasized, however, that it is not for the sake of accountability, but for the purpose of prevention, to develop a safety culture. (Mearns, 2017; Jazayeri, 2017)

1. CONSIDERATION OF HUMAN FACTORS

According to Russell Ferrell's theory of human factors (Hosseinian, Torghabeh 2012), human factor in the cause of an accident suggest that employee behavior may change by internal or external factors. A person may be overloaded due to the person's capacity and the imbalances. This situation can cause that the person becomes vulnerable to a possible accident or an operational problem. Russell Ferrell, a professor of human factors at the University of Arizona, according to his proposal on human factors, states the accident is a consequence of a chain of incidents caused by "human error" and has three main factors:

1. Overload: This refers to how much an employee is able to perform at a given time and what weight or burden they are burdened at that time and under given circumstances. An employee's ability refers to a person's physical condition, natural ability, state of mind, education, expertise, skill, level of stress, or fatigue. The state of mind of employees is the result of their level of motivation and excitement. Overload can be caused by:
    - external environmental factors such as noise, thermal problems or distractions,
    - internal factors such as emotional stress, illness or personal problems,
    - situational factors such as the degree of risk and unclear, incorrect or illegal instructions.

2. Incorrect response (incompatibility): This refers to the fact that the employee may react incorrectly when operating under "overload" conditions and thus cause an accident, a technological problem, such as:
    - when an employee gives an incompatible or inappropriate response in a particular or stressful situation,
    - when the employee does not report an obvious and identified hazard or a problem,
    - when the safety protective cover of machines have been removed, usually to increase production,
    - if safety procedures are ignored.

3. Improper Activities: An employee may have acted improperly because he or she did not know how to perform the task or intentionally risked because he or she thought there was no accident or was unaware of the extent of the damage caused by the problem. Improper activities can be caused by human behavior, such as when an employee performs a task without the necessary knowledge, skills, and experience, and misjudges the degree of risk that could result in deviation from normal operating conditions, an accident, or injury. (Rielander, 2016)

4. Omission and commission: Human errors are generally (Reer, 2008) classified into errors of commission (EOC) and errors of omission (EOO). The first group relates to errors that occur during the identification, interpretation, and execution phases of a specific activity, so the operation is not performed as expected. The second category refers to errors resulting from forgetfulness or inattention, leaving a step in the task or the task itself. Errors of commission can be eliminated with appropriate instructions, procedures and training. To prevent errors of omission, the solution can be to have a detection mechanism (eg an alarm) attached to the critical process elements. (Carpitella, 2018)

2. INCIDENT PREVENTION OPPORTUNITIES

Incidents are unplanned and can be avoided in most cases. Several experts provided guidance on incident prevention. These are the follows:

- Paying attention to a particular workflow helps prevent events and provides better productivity.

- Wearing suitable work clothes and personal protective equipment.
- The employer must inform employees about the dangers to health and safe work. However, the employee also has a duty to inquire and request information about hazards, unsafe activities, and unsafe conditions.
- The employer must ensure that people are properly trained in the tasks or activities they perform. Never ask people to try to perform tasks or activities if they are not competent to handle.
- Plan and organize work tasks or activities to identify potential hazards before starting work.
- The employee should make sure they know the workflows before starting a task or activity. Clarify and indicate unclear instructions.
- Never perform shortcuts. Always perform a task or activity in accordance with work and safety procedures.
- Be aware of potential incidents and report them to management immediately.
- Employers must ensure that the correct safety signs are clearly visible.
- The health and safety of workers must take precedence over profit and productivity.
- All employees should be actively involved in safety drills.
- Environmental order is an important consideration in event prevention.
- All workers should enter the workplace with a critical eye and consider potential safety issues. (Rielander, 2016)

Of course, the above should also be part of the policy and basic operating principles of a company operating a safety management system, but the experience is that these are not emphasized enough and quite often by plants engaged in hazardous activities. Incident investigation should therefore also play an important role in the safety management system so that lessons learned from all incidents that have occurred and are investigated can be incorporated into the system, thus avoiding its repetition and increasing the level of technological safety.

3. IMPROVING INCIDENT INVESTIGATION

In the case of a company dealing with hazardous substances, it is crucial that incidents that also affect safety aspects during production are investigated. This is shown in a logically structured system in Figure 1, which discusses the “mandatory” basic elements of the investigation process, but this can be improved so that more efficient results can be achieved.

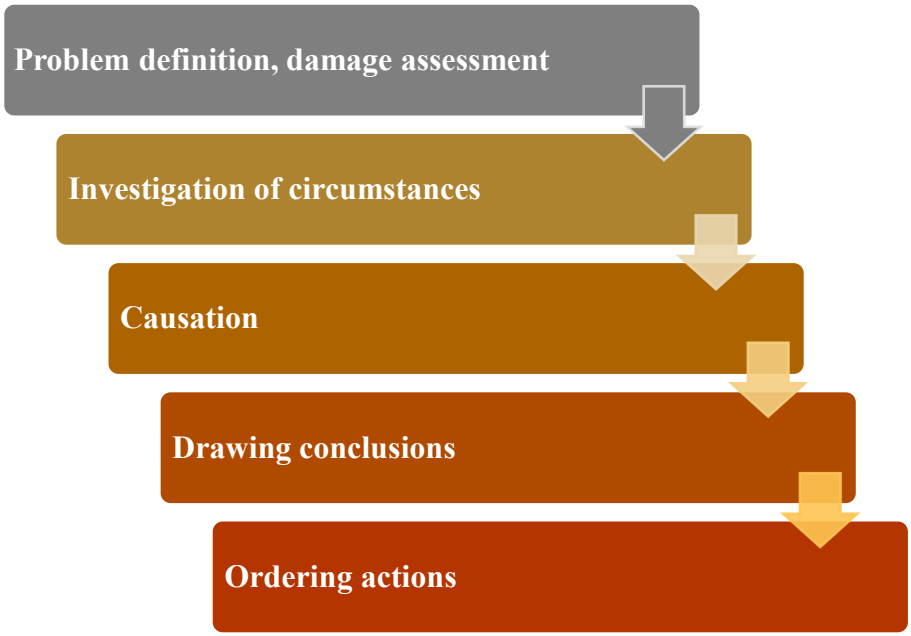

Figure 1: Elements of incident investigation

Damage, circumstances, cause(s), conclusions and actions should be key concepts in the incident investigation process. An incident investigation can be considered successful by a company if the root causes are identified and then not only action is taken on them, but as new, identified risks are included in the assessed and managed risks.

The reason for investigating incidents is to collect information about the cause of the incident, to determine the cause, and to collect the facts and evidence that support it. Investigating an incident is not a debugging mission and is not intended to blame the individual. The aim is to identify ways of repetition and prevention of the accident. Experts refer to two main types of incident investigations. These are event reports and event analysis reports. For minor events, an event report is prepared that answers who, what, where, and when questions; it does not deal with why or how. The incident analysis report was prepared for a serious incident; it answers who, what, where, when and how questions and takes place almost as a formal investigation. (Rielander, 2016)

The former still happens in that way in larger companies. However, minor incidents or incidents that do not involve the release of hazardous materials and deviate from normal operation are in many cases not investigated in sufficient depth due to the defined prioritization system or capacity problems. The increase in the safety culture of companies is also shown by the fact that the number of more serious problems is already decreasing and investigations are focused on the investigation of the causes of the former categories. The measures of these, mainly the results of the investigation of technological and operational problems, will largely serve the prevention. In order to apply a detailed analytical method to the investigation of what incidents, it is necessary to define aspects that can be used to quickly decide which one to deal with at what depth. There are several ways to do this, e.g. we can follow the principles of informal analysis using checklists, with problems systematized so far, or the principles of systematic analysis such as e.g. fault tree analysis or event analysis. The point is that we can decide in a short time whether the incident is “worthwhile” for a deeper investigation. In this case, it must be examined that

- how many times the deviation from normal operation has occurred in a given period,
- has caused any loss of production,
- caused a problem affecting another organizational unit,
- could have caused this safety problem,
- whether the root cause can be unambiguously defined.

By putting these in the right form in the safety management system, plant managers can determine the depth of the investigation themselves, so that professional leaders can be involved.

4. METHODOLOGICAL DEVELOPMENT OF EVENT INVESTIGATION

Maintaining an injury-free workplace is difficult due to the inherent uncertainty of the built environment. In a well-functioning safety management system, where the causes of incidents can be identified and eliminated, the number of incidents can be reduced. The company’s professionals can identify the roots with effective, guided, retrospective and forward-looking investigations, so lessons learned from the incidents are incorporated into ongoing development efforts. The main goal is to identify the causes leading to the “undesirable” outcome so that the leader takes appropriate corrective and preventive action. Many safety professionals agree that improving the quality of incident investigation reports can improve safety performance. One way to improve the incident investigation framework is to use six sigma DMAIC (define, measure, analyse, improve, control) cycle. (Karakhan, 2017) (Karakhan, Alsaffar, 2013) (Ferreira, Lopes, 2010) (Behm, Powell, 2014)

The DMAIC cycle is a well-structured methodology used not only to find the causes of errors within the production system, but also to eliminate the causes of errors and improve the quality of production. The process includes identifying the problem, measuring and then analyzing the data to identify possible causes, and improving the process by eliminating the root causes of the errors.

The define phase

It consists of identifying the process and determining the scope of the problem. Used to investigate an incident, the investigation team determines the type of incident (e.g., deviation from normal operation, accident, audit, etc.) and then identifies the employees, subcontractors, and all other interacting project

teams involved in the operation. At this point, the team can share illustrative tools to increase understanding. (Karakhan 2017)

The measure phase

Its main purpose is to assess safety performance and collect relevant data to answer what and how questions. The first step in investigating an incident is to determine the frequency and severity, which will help determine the level of risk and the impact of the incident on employee safety, morale, and costs. There are four levels of severity associated with the events: 1) negligible; 2) low level of severity; 3) moderate severity; and 4) high level of severity. Event categories should be well defined according to the nature of the event (eg personal injury, release of hazardous materials, significant economic damage, etc.) and assigned severity levels, but it should be taken into account that negligible and low severity events do not necessarily mean low security risk. Conducting face-to-face and focus group interviews on the incident is an effective way to collect relevant data before linking this data to the questions asked in the next DMAIC section. On-site safety audits, safety checklists, and employee observations are also useful methods for collecting usable data. (Karakhan 2017) (Jannadi, Almishari, 2003)

To get a complex picture of the circumstances of an incident and to analyze it with results in the next phase, in addition to the above, in the case of companies operating hazardous technology, it is necessary to collect the documents and instructions regulating the operations. The parameter trends of the technological process control system for the given period provide a great help in the analysis of the data too.

The analyse phase

The third phase of DMAIC is the analyse phase. The data obtained in the previous phases are analyzed to determine causal contexts as precursors to identify the root causes of primary events. This phase paves the way for management strategies to implement threat elimination and improve safety performance. To address the root causes and identify potential areas for improvement, the team should review all indicators leading to the incident through investigation reports, by screening past incidents, injuries, on-site safety audits, occupational safety analyzes, occupational hazard analyzes, and similar information. However, before choosing development strategies, the team needs to make sure that the root causes, not just the symptoms, are identified. At this stage, the team involved in the investigation can often use graphical tools such as histograms, Pareto diagrams, and causal fishbone diagrams.

For example, the five Why (5W) device can be used to explore and identify roots or causes. This is a systematic problem-solving technique used to explore causal relationships. After identifying the causes of the event the team may use techniques such as failure mode and effects analysis to assign a risk value to each cause. (Karakhan, 2017) (Rancour, McCracken, 2000) (Serrat, 2009) (Manuele, 2016)

In fact, a consequence analysis needs to be done to record and thereby clarify which causes have led or could lead to what consequences. Although it is not specifically mentioned in the guidelines on incident investigations published in Hungary, as well as in most of the literature, the investigation of responsibilities should be singled out at this stage. If we consider this as one of the main aspects, we also examine the level of personal responsibility, human omissions, behavior and safety culture. This can be done e.g. by reviewing work instructions, job descriptions, contracts, regulations. The reasons thus identified may also provide a clear direction for the development of safety-conscious behavior. At this point, responsibilities are worth examining at three levels. These are the personal responsibility (employees, planners, project managers, supervisors), the managerial responsibility (approvers, issuers of instructions) and the organizational responsibility (resource providers, decision makers).

The improve phase

The main purpose of incident investigations is to identify the causes of failure and then implement effective countermeasures to prevent repetition of events and improve the safety performance of the project. Based on the information and analysis collected in the first three phases, possible corrective and preventive actions are considered in the improve phase. The investigation team needs to understand the difference between corrective and preventive action. Corrective action is directed at the immediate causes of the incident and, in general, at mitigating and curbing the effects of the accident. The purpose of preventive actions is to anticipate and prevent incidents before they occur. However,

these actions can only be effective if the root causes are properly identified. Corrective and preventive actions can take various forms. For example, management may organize employee awareness training if the investigation reveals that employees lack a sense of safety. (Karakhan, 2017) (Powell, 2013)

The control phase

The control phase includes the verification and maintenance of safety gains realized after the implementation of incident prevention countermeasures. Maintaining safety performance over time is critical, but it can be a significant challenge for companies. In a manufacturing environment, when six sigma DMAIC cycles are implemented to improve quality performance, quality circles are used to engage employees in the decision-making process. Quality circles are made up of employees who regularly discuss ways to improve quality performance. In the case of a company engaged in a hazardous activity, management can create safety circles to involve employees in improving the safety performance of the activity, identifying safety risks to develop safe operations that can lead to better results. To do this, management must select employees and on-site supervisors to lead the groups. (Karakhan, 2017) (Granger, 2012) (Powell, 2013)

In the Define and Measure phase of the DMAIC method, we can also use effective tools to help clarify the problem and data definition, as well as the initial definition of the circumstances, thus giving a clear and transparent picture to the participants in the incident investigation. One such tool is the SIPOC diagram, which is used by a team taking into account suppliers, process participants, designers, project managers, etc. (S-Suppliers), process inputs (I-Inputs), process itself (P-Process), process outputs (O-Outputs) and customers, affected, injured, etc. (C-Customers). It helps define the boundaries and critical elements of the process. This tool helps to demonstrate the safety contribution and responsibilities of each party in the plant. (Karakhan, 2017)

The device can be used most effectively as shown in the following figure:

Suppliers (Those involved in the circumstances of the incident)	***Inputs***	***Process***	***Outputs***	***Customers (Those involved in the effects of the incident)***	***Requirements / immediate actions***
Designers	Operational instructions		Number of injured	Employees/operators	First Aid
Employees/Operators	Standards		Environmental damage	Maintainers	Troubleshooting
Projekt manager	Technological plans		Authority action	Neighboring economic entities	Information
Maintainers	Technological trends		Material damage	Population	Withdrawal
	Review reports				
	Supporting documents for the startup				

Figure 2 SIPOC diagram

It is important to look at each category in relation to the activity, as it is mainly used in quality management. However, its benefits are also significant for safety engineering incident investigations because it systematizes the amount of data collected in the initial stages of the investigation.

The above method and its supplementation, as well as its projection to enterprises operating hazardous technologies, provide an opportunity for the incident investigation element of the safety management system to demonstrably increase safety performance.

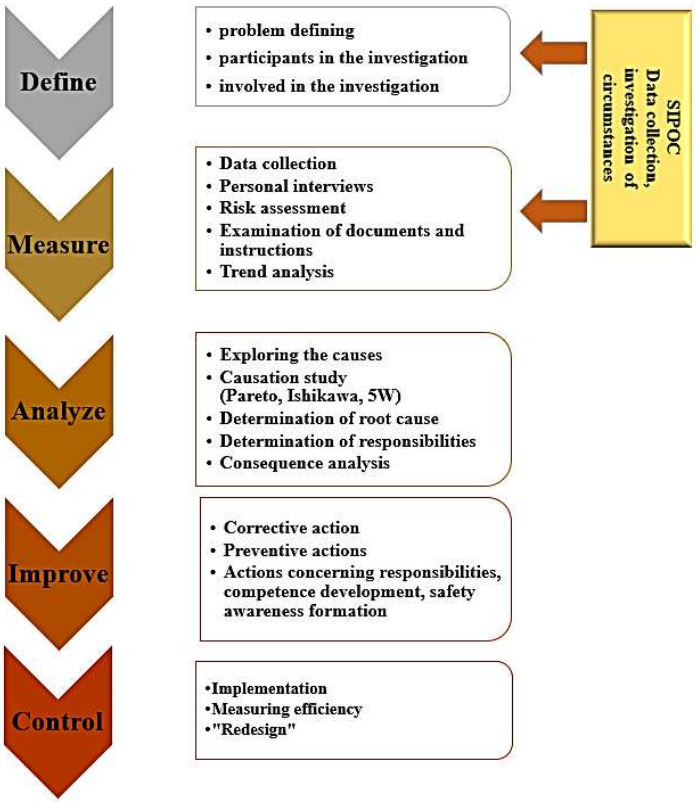

Figure 3 Incident investigation according to the DMAIC method using SIPOC diagram

Thus, by incorporating the DMAIC principle into the incident investigation methodology, we receive a much more understandable, and more logical process that provides understanding to those involved in the investigation, guiding the process so that all circumstances, causes, responsibilities and actions, with which similar events and technological problems can be avoided and prevented in the future, and with the help of which the system approach and safety awareness of the employees will also develop. In terms of investigations, the initial steps should be emphasized, where precise problem identification and the collection of all relevant data will facilitate further process elements. This can be achieved using the SIPOC diagram and following its methodology.

CONCLUSION

Using the six sigma DMAIC model as the main line of incident investigations, a more transparent, logical process can be built to support the incident investigation practices of companies engaged in hazardous activities. To help and facilitate the initial stages of the investigation process, the use of the SIPOC diagram is for easier understanding, making the investigation of additional process elements clearer and more complete.

In the analysis phase of the process, a more pronounced examination of responsibilities and the development measures taken for it, according to practical experience, play a major role in shaping the safety awareness of employees.

In order to increase efficiency, by highlighting the good practices of the currently used systems, which are based on effective internal communication, continuous improvement, and the establishment of responsibilities, we can minimize the risks that occur during the activity. By applying the DMAIC principle, focusing on responsibility, and applying incident investigations at a high level and appropriately, the emergence of further similar cases could be prevented.

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