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The use of statistical problem solving methods for Risk Assessment

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Abstract

It is typical, also in agriculture industry, that safety is a performance area in which it is difficult to plan and control a real improvement. The normal approach to safety improvement is through Risk Assessment. Unfortunately this approach is strongly limited because the evaluation of the risks is based on evaluator's experience and expertise and so it is affected by low level of reliability.
The aim of this paper is to show how the use of statistical problem solving method, such as Six Sigma, could be useful to improve safety level in working activities. In particular high level of improvement could be obtained by a more structured collection of injuries data considering not only the injuries frequency rate related to the root causes or risks. Following several instructions it could be possible to obtain a database of Risk Indicators based on real data that could be used for a more reliable Risk Assessment.

Keywords: Risk Assessment, Six Sigma, Root Causes Analysis, Stratification, Risk Indicators.

Introduction

Every few minutes somebody in the world dies from work-related causes and every year hundreds of thousands of employees are involved from injuries during work activities. The potential financial devastation caused by the costs associated with accidents necessitates the adoption of an improvement process in the areas of safety, health, and environmental protection. During the last years high technological progresses have been made about safety and health in working activities. Even if the safety rules have became stricter and the concept of risk assessment is now well established and forms the basis of health and safety legislation, the work injury is still a big problem as it is clearly shows by statistics related to many terrible events.

In the industrial field, the accidents situation depends on a wide variety of causes (i.e. diversification and complexity in production processes and technologies, human factors, organization aspects, no application of safety procedures) that are often very difficult to indentify and to analyze. This is the reason why today a proactive approach to safety problems becomes a key factor. The Risk Assessment approach is already known and consolidated; but the problem that is not yet solved is related to the indicators used in order to identify the order of risk priority. Usually these indicators are based on evaluator's experience and expertise, and not necessary deriving from statistical analysis. It is strongly needed to identify more objective principles that allow to characterize the risks in a better way.

This work shows the strong contribution that could be given by a statistical analysis of work injury data in each industrial field. These data are usually available but it is very difficult to use them for risk estimation phase. Therefore, it should be useful to find the relationships between injuries and the real conditions in which these injuries happened. In that way it could be possible to create statistical indicators for each kind of risk. The aim of this paper is to explain, with a guideline, how the injuries data should be collected to obtain a database of statistical risk indicators that could be used for Risk Assessment. This guideline is developed using the Six Sigma Approach that is a statistical problem solving method.

Risk Assessment Approach

Risk assessment represents a careful analysis of the premises, processes and work activities to identify what could cause harm to people to enable decisions to be made as to whether sufficient precautions have already been taken or whether further controls are needed. The aim of Risk Assessment it to individualize an order of risk priority that allow to define a hierarchy of intervention activities (design review, procedures, formation and information) needed to eliminate or reduce the risk. There are many methods for Risk Assessment (FMEA, FTA, HAZOP, What-if, MOZAR, etc.) [Hiromitsu K., 1996] that are all usable. The identification of hazard typology to analyze (ordinary hazards or specific hazards such as noise, vibration) usually establishes what risk assessment techniques should be used as similar techniques may not necessarily yield the same results.

Risk assessment techniques may be either 'subjective – qualitative' or 'objective – quantitative' and their differences are strictly related to the indicator typology.

Qualitative techniques are comparatively cheap and readily applied but are unable to provide numerical estimates and therefore relative ranking of identified risks. Semi quantitative techniques allow some relative risk ranking, but these techniques are still unable to provide detailed assessments of system safety, effects of common cause failures and redundancy features. Similarly neither can effectively be used in the prediction of low frequency high consequence events – i.e. catastrophic risks.

Quantitative methods overcome these shortfalls and are ideally applied where system safety and criticality is to be assessed; but they require a more rigorous approach to recording and interpreting incident, accident and maintenance information to provide accurate and auditable inputs to those studies.

The Risk Assessment usually passes trough the following five steps [OSHA - factsheet 81. 2008]:

1. Identifying hazards and those at risk
2. Evaluating and prioritizing risks
3. Deciding on preventive action
4. Taking action
5. Monitoring and reviewing

The paper is focused on the 2^{nd} step that implies to consider:

- ■ - how likely it is that a hazard will cause harm;
- ■ - how serious that harm is likely to be;
- ■ - how often (and how many) workers are exposed.
- ■ - what are the root cause(s)

The level of risk can be expressed by means of tailored indicators (such as the severity, occurrence, exposure) which in turn are described either qualitatively (i.e. by putting risk into categories such as 'high', 'medium' or 'low') or quantitatively (with a numerical estimate based on statistical data).

Six Sigma method

Six Sigma is a highly disciplined process that helps to focus on developing and delivering near-perfect products and services. The central idea behind Six Sigma is that if you are able to measure how many "defects" you have in a process, you can systematically figure out how to eliminate them and get as close to "zero defects" as possible [Citti, 2004, Breyfogle, 1999]. This approach can be extended to safety problems considering each work injuries as a defect of the process.

The Six Sigma approach is composed by five steps: Define, Measure, Analyze, Improve and Control that compose the DMAIC algorithm (Fig.1).

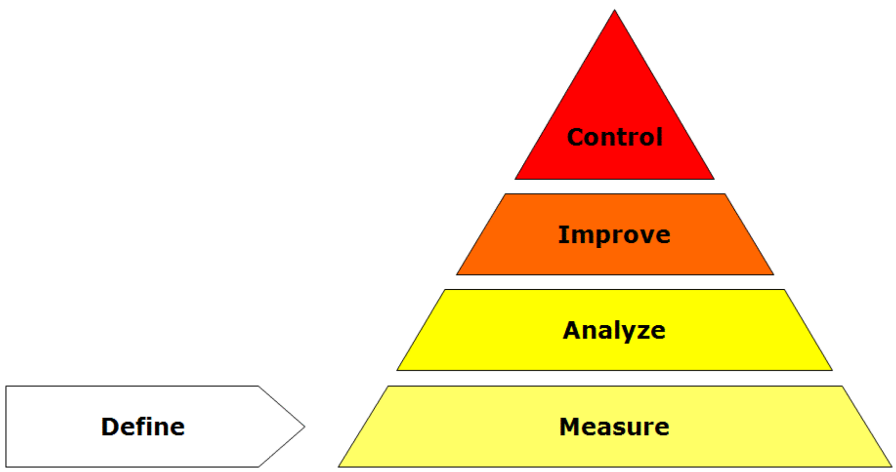

Figure 1. The DMAIC Algorithm used in Six Sigma Project

Define is the phase in which project goals and project boundaries are identify, so it is the phase that defines the problem that needs to be solved. In this phase, the goal is to pinpoint the location or source of the problem as precisely as possible by building a factual understanding of existing process conditions and problems. Having this knowledge will assist you in narrowing the range of potential causes that are needed to investigate in the Analyze phase.

The Measure phase measures the actual performance of the process. Having stratified the data in the baseline performance, it becomes possible to pinpoint the location or source of the problems by building a factual understanding of the existing process conditions and problems, which will help to focus the problem statement.

In the Analyze phase the goal is to identify root causes and confirm those on the basis of data. The verified causes will then form the basis for your solutions in the Improve phase.

In the Improve phase many possible solutions are created and developed. These solution are evaluated in terms of capability to eliminate or to reduce the impact of the identified root causes. The goal should be to demonstrate, through an experiment, that one or more of the identified solutions solve the problem and lead to improvement. During the Improve phase, the solution is piloted, and a plans for a full-scale implementation is made.

In the Control phase the results are verified and planned to maintain the gains accomplished. Control is to make sure that the is corrected and that the new methods can be improved upon further over time.

Six Sigma for Safety Risk Assessment

An analysis of the existing work injuries database shows that they are completely focused on the description of the occurrence and the severity related to the events. For this reason the traditional databases are usually useful only to describe the impact of work injuries problem and so they cannot be functional to Risk Assessment indicators. This depends on the fact that in the existing database there are no connection between the injuries and their root causes. A more complete approach suggests to consider injuries as the consequence of a malfunction in the safety process. In this direction Six Sigma method could help the identification of the probability for each risk by the collection and analysis of appropriate historical data. In this way the use of Six Sigma method, instead of a traditional reactive problem solving methods, can drives to the identification of the real causes of the problems and consequently to the safety improvement of the work place (Fig.2).

	Traditional Approach	Six Sigma Approach
Problem	Focus on symptoms	Focus on causes
Behaviour	Reactive	Proactive
Decision	Based on impressions	Based on data
Analysis	Analysis of injury statistics	Root causes investigation

Figure 2. Comparison between traditional and Six Sigma Approach to problem solving

The Six Sigma approach starts from the real injuries data and then goes back to the root causes.

This path could be done through three main activities:

- Stratification and Investigation to obtain the highest information content from the real injuries data and to identify the root causes of each injury (Fig.3);
- Development of measurable Indicators through which it could be possible to prevent the occurrence of new injuries.

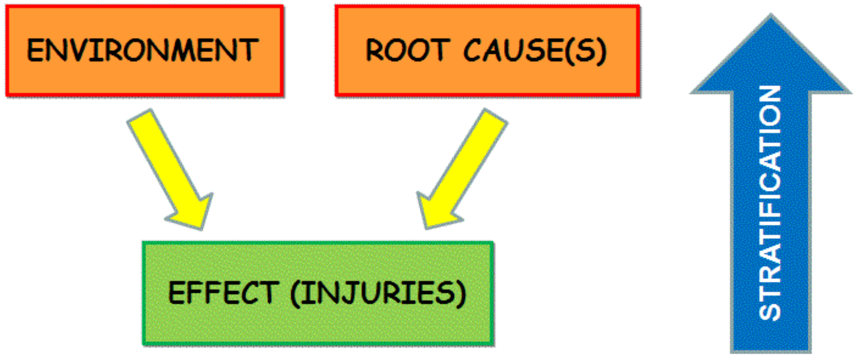

Figure 3. The path from Injury to Root Causes through the use of stratification

Stratification

A first factor to obtain good results using the DMAIC algorithm is the stratification of data. Stratification of data means that each data is collected recording also many connected information. Therefore, the process of data stratification consists in collecting the injury data break it down into layers. The questions who, what, when, and where represent possible layers, in particular:

- The WHO layer – The question "who" is intended to define who is associated with the problem (the characteristics of the injured person should be collected);
- The WHAT layer – The question "what" defines the type of problem which is occurring (type of injury);
- The WHEN layer – The question "when" focuses on temporal context of the injury;
- The WHERE layer – The "where" question clarifies where a problem occurs (regards the environment in which the injury occurs).

This model supports to clarify the problem and its impact. The traceability of this information is necessary to reveal also the root causes of the accident happened [Pande, 2001].

Investigation

The second activity is the Investigation [Marcel, 2002] that is the analysis and representation of the "HOWs and WHYs" of the injury. Investigation is divided in two parts (Fig.4):

- The determination of the events sequence (HOW's) that causes the accident: the events are portrayed graphically through an Event Diagram by arranging them, often chronologically left to right in rectangles, in a logical flow indicating 'what' happened. This sequence of events often, if not always, extends beyond the time of the accident event to include circumstances of the post-accident phase.
- The identification of Underlying Factors and Unsafe Conditions: once the sequence of events diagram is completed, safety significance events can be easily identified for further investigation or analysis to determine "why" it happened. In order to understand the "how and why" of the accident, the investigators need to identify the relevant contributing conditions and underlying factors of such safety significant events. In many situations, investigators cannot confirm, with certainty, why an accident happened. However, short

of determining "why" it happened, we can often find information that can be used to reduce risk. This step helps to create a database that correlates the events with the causes. All the results of the investigation analysis are also used to define a correct stratification of data.

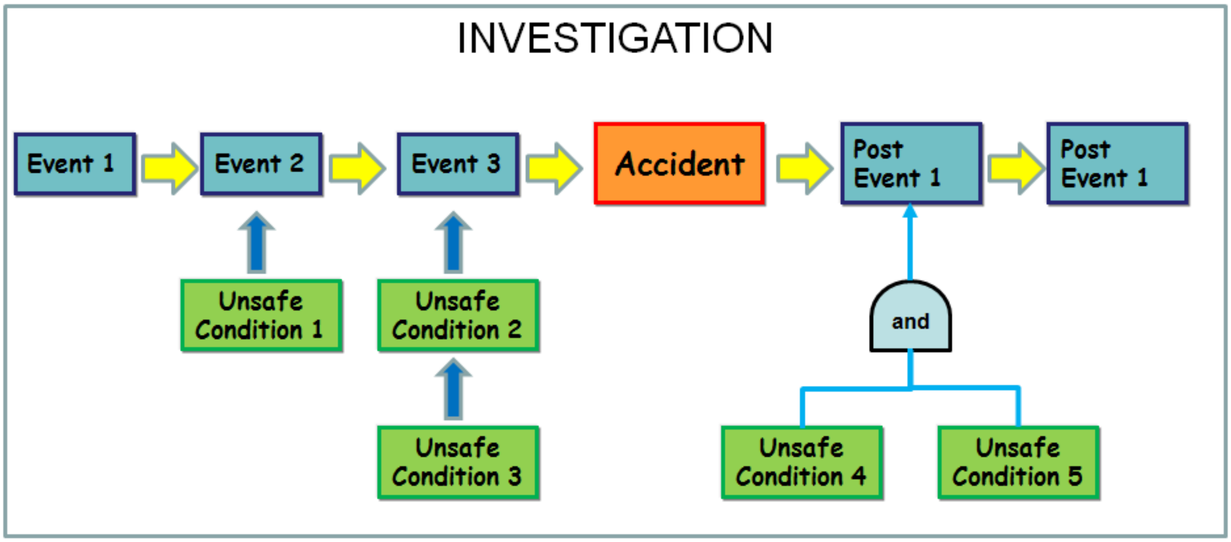

Figure 4: A typical scheme of Investigation results

Safety Indicators

Unfortunately the measure of safety performance has traditionally been accomplished only by means of accident rates, such as Injury Frequency Rate (IFR) or Severity Rate (SR), that are typically categorized only according to the frequency and severity of the accident. On the other hand, significant safety factors are identified by discovering statistically significant correlations between unsafe conditions and the injuries rate data [Grabowski et al, 2007]. These kind of correlations, identified using stratified data, can be functional to the Statistical Evaluation of Risks Index (Fig.5) referred to each cause. It is important to notice that using this approach we can learn by each mistakes and improve our safety processes continuously. For all these reason the last critical activity is the development of indicators for safety performance [Murdoch, 2006]. This is needed because many of the Six Sigma tools, such as Control Charts, Run Charts, and Pareto Diagrams, can be used to track and monitor safety performance, establish trends, and evaluate program performance against accepted tolerances only if there is a clear indicator that can be monitored.

There are two kinds of indicators:

- Trailing Indicators that are based on facts related to past events, such as injury rates, and are usually used to describe the problem.
- Leading Indicators that are connected to the conditions and activities that come before the occurrence of workplace injuries and illness. They measure the level of safety on a jobsite even when no injuries have occurred. Leading Indicators are usually strongly connected with root causes.

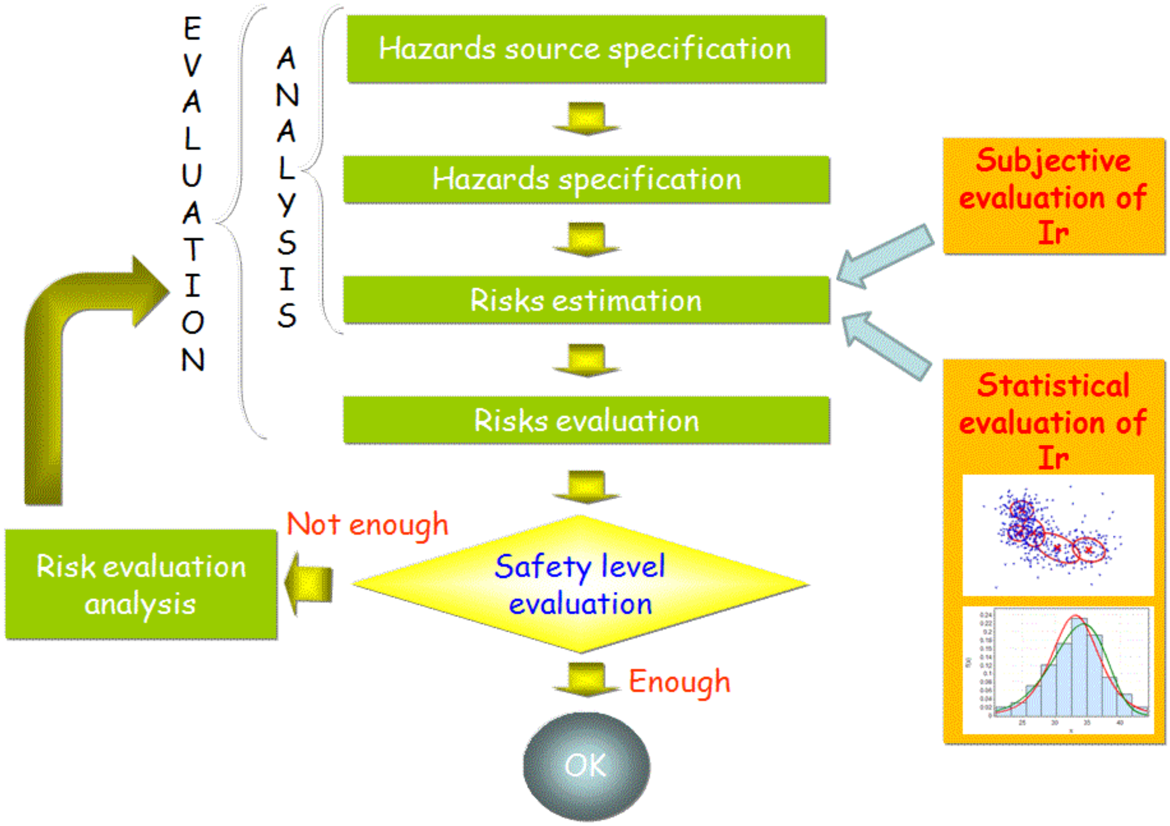

Figure 5: The Statistical Evaluation of Risk Index (Ir) is part of risk estimation step of Risk Assessment logic algorithm

It is important to notice that the development of the leading indicator focuses the attention on the precursors of the injuries. The precursors are the events or situations that could lead both to minor and catastrophic incidents, The entity of the effect depends on slight differences in a small set of behaviors or conditions. Consequently the development of a good skill in precursors identification is a key aspect of injuries analysis. This is mostly due to the following consideration: it is demonstrated by empirical evaluation [Phimister, Bier. 2004] that for each serious injury, about 10 minor injuries and 1000 near miss or property damage incidents should be expected. This is important because the same conditions and causes (the same main precursors) that contribute to minor incidents also contribute to serious ones (Fig.6). The pyramid scheme explains that a single serious incident at the peak has the same root causes of a broad base of non-injury incidents. In that way it is possible to consider an extended amount of data and a consequently accurate risk index even if only few major injuries occur.

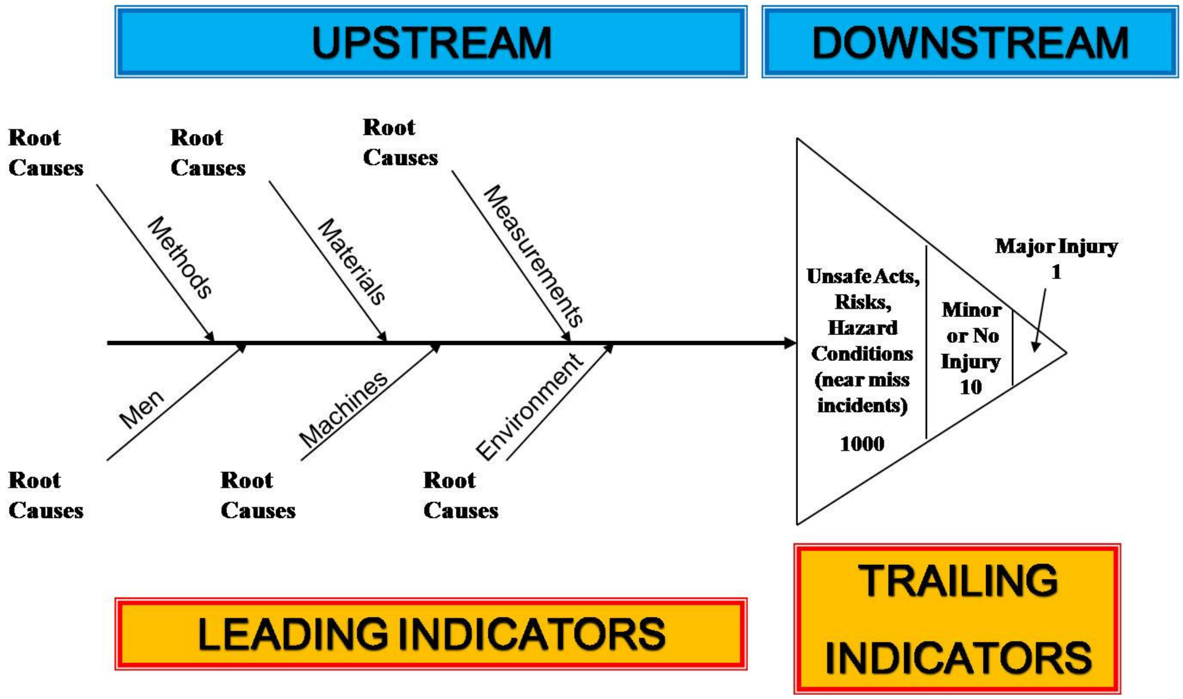

Figure 6: Evolution of Cause and Effect Diagram to show all the data that could be collected in the stratification: upstream with the collection of root causes and downstream with the collection of minor incidents and serious incidents rate

Conclusions

This paper provide some guidelines to develop a correct data collection that allows to define Risk Index based on statistical data instead of subjective factors. At this proposal, particular attention is dedicated to the identification of relationships between root causes and injuries, considering both serious injuries, minor injuries and property damage incidents. In fact, a real improvement in Risk Assessment is strongly related to the skill of collecting useful data when a major or minor injury or a near miss occurs. Six Sigma is the method used to approach the problem; particularly, the proposed path is based on data Stratification, Root Causes Analysis and the development of tailored indicators. Following this approach a database related to a specific industrial context (such as agriculture industry) could be developed. This database with a sufficient amount of real data can support a quantitative/objective risk assessment approach.

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