PRIORITISING THE SAFETY MANAGEMENT ELEMENTS THROUGH AHP MODEL AND KEY PERFORMANCE INDICATORS

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ABSTRACT
Safety management is considered a basic component of any firm's safety culture in various models. In fact, accidents at workplace not only provoke a decrease in human capital; they also generate financial losses. Nowadays, the organizations have been searching for continuous improvement within this specific issue. The objective of this work is to develop a multicriteria model to evaluate the performance of process safety management system. More specifically, the purpose of the study is to present a hierarchy decision model for assessing the priority of elements of goals of OHSAS 18001 by using the Analytic Hierarchy Process (AHP) methodology and to select a set of KPIs for measuring safety performance. A real case study is analyzed.

Keywords: OHSAS 18001, AHP, performance measurement, decision support system, KPIs

1. INTRODUCTION

Today, any firms encounter pressure from multiple stakeholders to manage occupational health and safety issues properly, systematically and transparently (Lo *et al.*, 2014). During the last decade academic literature has emphasized the central role of occupational health and safety management as a key long range strategy, as it helps improve health at work and alleviate the different costs of work accidents (Frick, 2011). Pagell *et al.* (2013) argued that safety must be treated as a key operational priority alongside cost, quality, flexibility, delivery and innovation. It is currently recognised that safety management plays an important part in achieving and maintaining a high level of safety (Mitchison and Papadakis, 1999).
Safety systems allow documenting safety processes and aim at minimising occupational risks within the business. Occupational Health and Safety Assessment Series (OHSAS) is the favored certification because the system has to be audited by an independent organization. OHSAS remains the most popular externally certified Occupational Health and Safety Management System - OHSMS (Fernández-Muniz *et al.*, 2012).
Since the certification was introduced in 1999, it has diffused rapidly, growing from 8399 certifications in 2003 to 56,251 in 2009. OHSAS certification improves the firm's sales performance, since certification may meet customers' safety requirements (Law *et al.*, 2006). The standard has been developed to be compatible with ISO 9001: 2008 (Quality) and ISO 14001:2004 (Environmental) management systems standards, in order to facilitate the integration of quality, environmental and occupational health and safety management systems by organizations, should they wish to do so.
OHSAS Standard uses a management approach tool called the PDCA cycle. PDCA is an ongoing process that enables an organization to establish, implement and maintain its health and safety policy based on top management leadership and commitment to the safety management system. The "Plan-Do-Check-Act Cycle," outlined below, demonstrates how safety management systems give operators a tool for constantly evaluating and improving their safety performance.
In this context the present paper aims to examine the connection between the adoption of the OHSAS 18001 standard and performance measurement within an Italian s consulting company. Firstly, the adoption of the OHSAS 18001 standard was analyzed. Secondly, a key performance indicators (KPIs) were developed to evaluate the effect of the safety standard on safety performance. The KPIs were identified using a multicriteria approach based on Analytic Hierarchy Process.
The rest of the paper is organized as follows. In Section 2 a literature review on safety management and multi criteria approach is presented. Section 3 describes the proposed model and a case study is analyzed. Section 4 presents discussion. Finally, in Section 5, conclusions are analyzed.

2. LITERATURE REVIEW

In recent decades, companies have improved the process management of the health and safety to reduce the number of accidents and to improve working condition. In particular, it is necessary to promote

measures of continuous improvement to improve working conditions (Lo *et al.,* 2014). The safety management plays an important role in achieving and maintaining a high level of safety (Mitchison and Papadakis, 1999). The interest for the health and safety of workers is extended to all industrialized countries. In the strategy's mandatory form, EU's Framework Directive (89/391/EEC) specifies how employers are to manage the work environment for half a billion Europeans (Frick, 2011). The Eurostat data shows the decreasing trend of accidents in the European Union in the manufacturing sector. In the last five years the decrease of accidents is about 40% in the manufacturing sector. The identification of hazards and their corresponding control measures provides the foundation for a safety program and essentially determines the scope, content and complexity of a successful occupational health and safety management system (Makin and Winder, 2008).

It is necessary to define the appropriate tools for documenting the safety processes and work to minimize the occupational hazards. Certified occupational health and safety management systems (OHSMS) have become an important instrument for companies in their efforts to ensure a healthy and safe work environment (Fernández-Muniz *et al.*, 2012 and Hohnen and Hasle, 2011). The Occupational Health and Safety Assessment Series (OHSAS) 18001 is the dominant international standard for evaluating safety management processes at the firm level (Granerud and Rocha, 2011). Abad *et al.* (2013), argue that businesses characterized by poor working and safety conditions would likely exhibit problems in their operations, and this negatively affects safety outcomes and operational performance. They analyze the relation between the adoption of the OHSAS 18001 and firm performance, as shown in Figure 1.

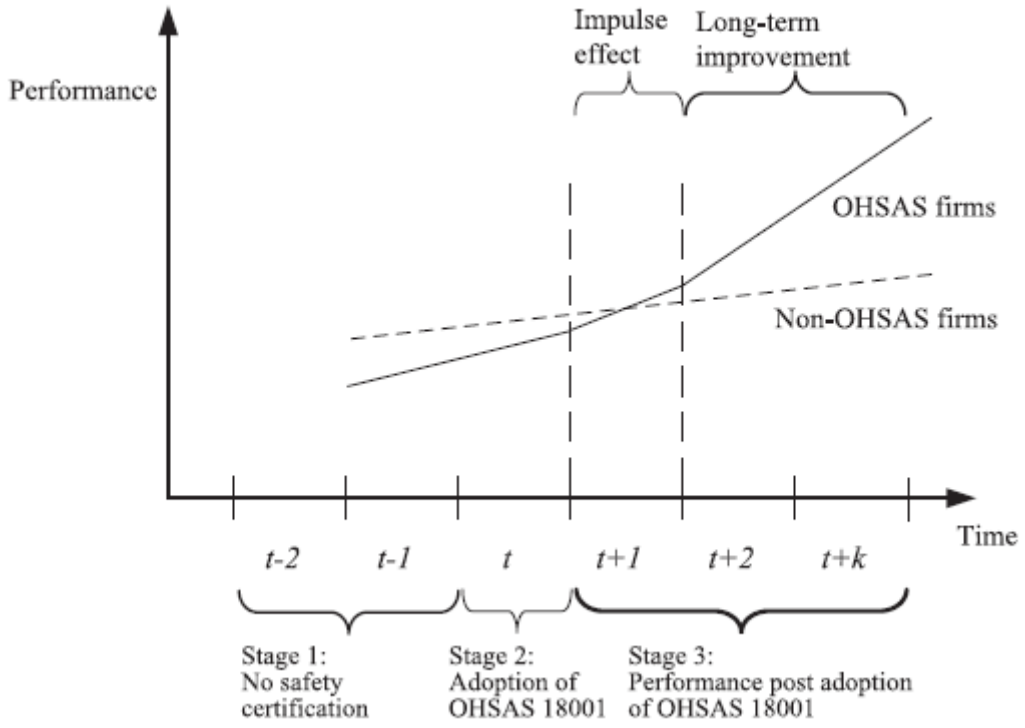

Figure 1: Relation between the adoption of the OHSAS and firm performance (Abad *et al.* 2013)

Vinodkumar and Bhasi (2011), study the impact of management system certification on safety management. The conclusions show that the safety system is closely related to quality ad environmental system, in fact OHSAS 18001 is compatible with ISO 9001: 2008 and ISO 14001.

When managing health and safety systems it is necessary to make choices, the complexity stems from a multitude of quantitative and qualitative factors influencing the choices (De Felice and Petrillo, 2013). It is necessary to identify a decision-making methodology that allows to make the best possible choice. The strategic decision-oriented health and safety includes a range of factors which involve both quantitative and qualitative. Extensive multi-criteria decision making approaches have been proposed such as the Analytic Hierarchy Process (AHP), Analytic Network Process (ANP), Case-Based Reasoning (CBR), Data Envelopment Analysis (DEA), Fuzzy set theory, Genetic Algorithm (GA), mathematical programming, simple multi-attribute rating technique (SMART), and their hybrids (Ho *et al*., 2010). Among the above method, one of the most popular is the AHP, used to solve complex decision problems and introduced by Saaty (1977). The strength of AHP is to breaks down a decision-making problem into several levels forming a

hierarchy with unidirectional hierarchical relationships between levels. Some applications of AHP are analyzed as following. Law *et al.*, (2006) using a hierarchical decision model (AHP) to evaluate the priority of safety management elements in manufacturing enterprises in Hong Kong. The model proposes a self-regulating system to implement the security features. De Felice *et al.*, 2016 present an integrated approach AHP to quantify the performance and effectiveness of risk management to evaluate emergency alternative problems. Prasad *et al.*, (2013) have proposed a hierarchical decision model to evaluate the priority of elements in view of OHSAS 18001 in the Indian construction sector. The infrastructures are divided into: transportation, urban infrastructure and utilities. Hsu and Wang (2011), define a complete and safety management system in the plans. The study identifies 43 key factors of security and 15 cultural dimensions. The AHP identifies the weights between the cultural dimensions. Podgórski (2015), uses the analytic hierarchy (AHP) to select key performance indicators to measure the health and safety management. In the end you get a KPI ranking. Aminbakhsh et *al.* (2013), manage the priorities of risks with AHP model in the construction sector. The model determines appropriate investments for prevention of accidents considering their costs. The choice is made through the decision-hierarchical methodology. Chang and Lian (2009), develop a safety assessment model of the processes in plants producing paints. The AHP model has defined the weights of the different design attributes. The model showed that companies certified ISO 18001 have a more efficient risk management.

Badri *et al.* (2012), propose an approach for the risk assessment by classifying the risk factors, through a decision-making approach implemented with the expert choiche software. Silva *et al.* (2009), use an AHP model to evaluate the most important organizational management aspects (environment, safety and health, quality) for a manufacturing company.

3. THE METHODOLOGICAL APPROACH

According to some studies a low level of safety performance is related to insufficient knowledge and competence in the domain of OHSAS (Blewett and O'Keeffe, 2011). Furthermore, it seems that companies believe that the only benefit from certification is the ability to "attract" customers. Thus, all other components of operational performance would remain unchanged after certification. The above considerations lead to the conclusion that it is necessary to search for new solutions and arrangements that would improve the performance of OHSAS, which would consequently result in a positive contribution to greater acceptance of these systems among employers, employees and other stakeholders. This study utilized a holistic method to solve the problems in measuring the safety management. The aim of this paper is to demonstrate the application of the AHP to assess the priority of elements of goals of OHSAS 18001 and to select a set of KPIs for measuring safety performance. Figure 2 shows the research framework.

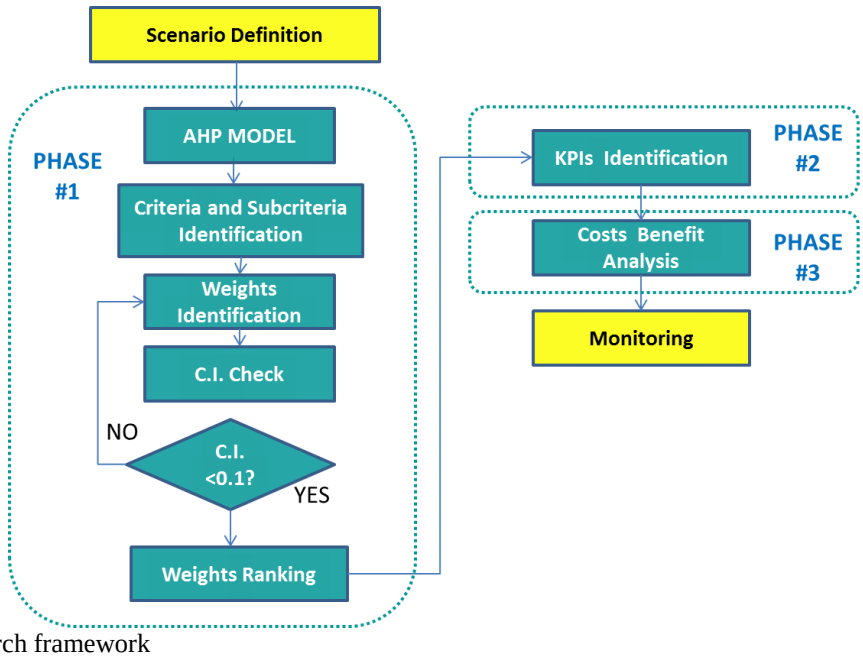

Figure 2: The research framework

3.1. Scenario definition

The case study was developed considering an Italian consulting company with 25 employees that operates in the IT and Engineering sector. The company aims to ensure the prevention, protection, health and safety of its employees. Thus, it decided to adopt an the OHSAS standard. The adoption of OHSAS standard requires a conscious organization and the identification of strategic safety management criteria. For this purpose a decision model was developed.

3.2. AHP Model: Phase#1

The decision model based on AHP framework was developed through a three-level hierarchy, as shown in Figure 3. The top level of the hierarchy is the main goal of the decision problem. The lower levels are criteria and subcriteria that contribute to the goal. The bottom level is formed by the alternatives to evaluate in terms of the criteria. The model is divided into three steps:

- Pairwise comparison and relative weight estimation;
- Priority weight vector calculation (identification of the solution);
- Consistency index estimation to verify the accuracy of the judgments.

The design of hierarchy required experience and knowledge of the specific problem. Thus, an expert team consisting of 1 safety management, 1 risk management, 1 expert consultant in OHSAS was formed. Expert team identified 4 criteria and 18 sub criteria. The model aims to select and to prioritize safety management indicators.

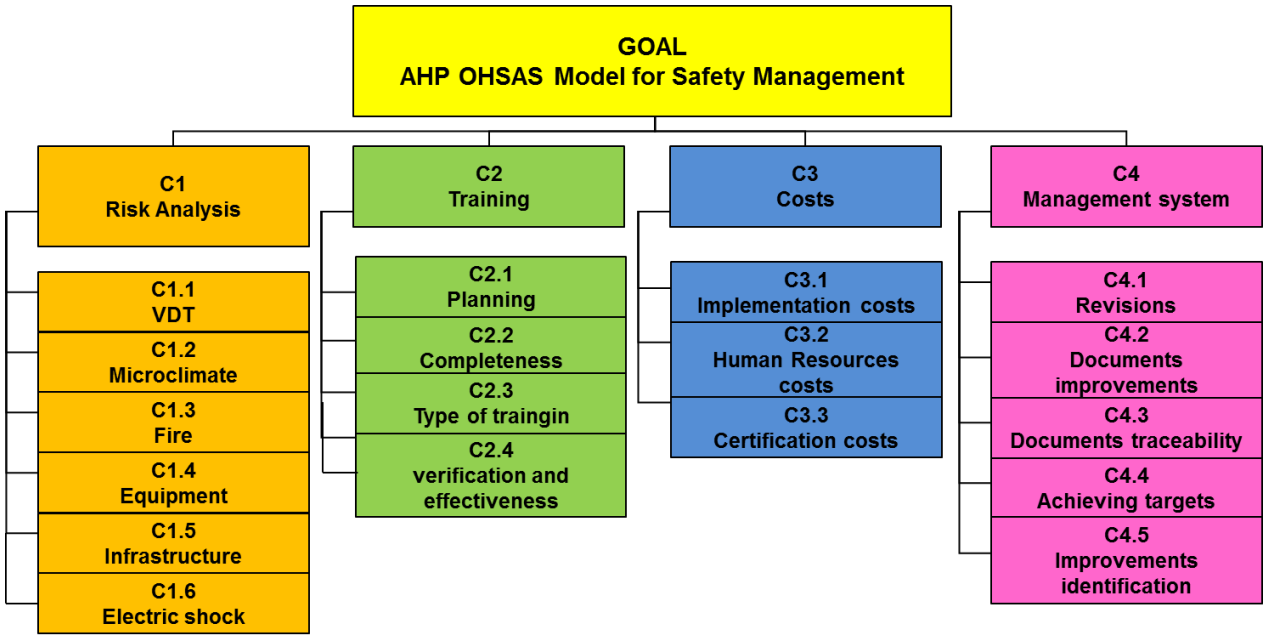

Figure 3: AHP OHSAS Model

After the hierarchy definition, the pairwise comparison matrices were developed in order determine the criteria and subcriteria weights. Table 1 shows an example of pairwise comparison for criteria.

Table 1: Example of pairwise comparison - criteria

	C1	C2	C3	C4.	Priority Vector
C1	1	3	2	1/2	0.301
C2	1/3	1	2	1/2	0.170
C3	1/2	1/2	1	1/3	0.117
C4	2	2	3	1	0.410
					CI = 0,061<0.10

Priority vector highlights that the most important criteria is C4 (Management System) with a score of 41%, followed by C1(Risk Analysis) with a score of 30%.

Figure 4 shows a summary of priorities for criteria and subcriteria.

The most important criteria are C1.1 (VDT risk) with a score of 36.9%; C2.1 (Planning) with a score of 46.6%; C3.3 (Certification costs) with a score of 62.5% and finally C4.1 (Revision) with a score of 44.4%.

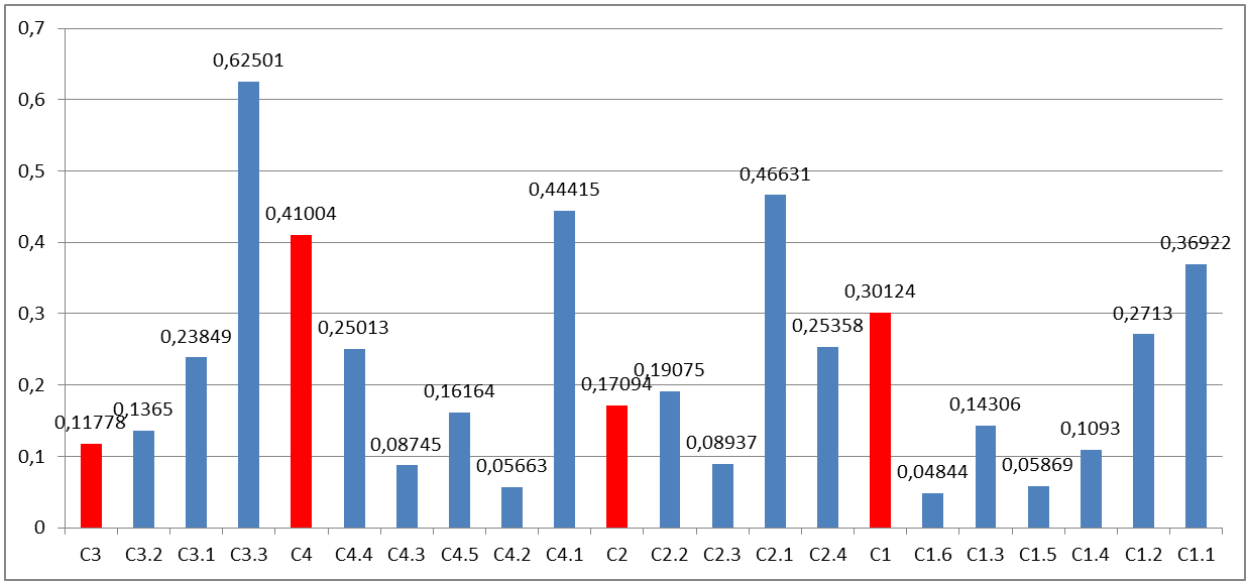

Figure 4: Summary of Priorities for criteria and sub criteria

3.3. KPIs identification: Phase#2

Success is defined in terms of making progress toward strategic goals. Thus, according the above results, KPIs were identified in order to evaluate the success of the company to implement the OHSAS standard. The choosing of the right KPIs was based upon a good understanding of what is important to the organization. Table 2 shows the selected KPIs.

Table 2: Example of selected KPIs

Criteria	KPIs
C1 Risk Analysis 30%	R1 = N° of eligible VDT workstations/ Total N° of VDT workstations
	R2 = N° of occupational diseases due to ergonomic/ Total N° of occupational diseases
	R3 = Total number of accidents/ N° of days of absence
C2 Training 17%	T1 = N° employees trained/Total N° of employees
	T2 = N° training courses executed/ training courses planned
	T3 = N° training courses executed/ N° employees trained
C3 Costs 12%	C1 = costs incurred for new procedures/ initial costs of OHSAS implementation
	C2 = costs for the implementation of the system OHSAS/Total costs
C4 Management system 41%	M1 = N° corrective actions implemented/N° corrective action planned
	M2 = Percentage of internal audits carried out versus plan

3.4. Costs Analysis (CA): Phase#3

A CA can help to make judgements on whether further risk reduction measures are reasonably practicable.
The main interest in assessing CA is to ensure that all the appropriate costs are included.
The total cost (CT) to implement the OHSAS standard is given by the following Equation (1):

$$CT = C3.1+C3.2+C3.3 \quad (1)$$

According to the weights calculated with the AHP method, the ratio, in percentage terms, for any costs in relation to the total cost is:

- C3.1 is 23.8% CT;
- C3.2 is 13.6% CT;
- C3.3 is 62.5% CT.

The above percentages are subject to change by 20% according to the discretion of the decision makers in the application of AHP methodology.
The next step was the identification of an algorithm to determine the total cost (CT) necessary to implement OHSAS standard taking into account 2 factors or the number of employees and the level of safety risk. At this purpose two coefficients were introduced: α and k.

Table 3 shows the variation of the coefficient α with the varying of the level of safety risk of the company.

Table 3: Coefficient α related to level of risk

Level of risk	Coefficient α
Low	1
Medium	1.5
High	2

The choice of α coefficient is a hypothesis based on the considerations that the costs rise progressively with increasing the level of safety risk. Expert team

established an increase of 50% in the pass between two consecutive levels.
While, Table 4 shows the variation of the coefficient k with the varying of the number of employees. In this case the expert team identified the variation of coefficient k considering that an increase of 25 employees, corresponds on average an increase of 20% of costs (that is, an increase of a factor of 0.2).

Table 4: Coefficient k related to number of employees

Number of employees	k
1-25	1
26-50	1,2
51-75	1,4
76-100	1,6
101-125	1,8
126-150	2
151-175	2,2
176-200	2,4

Therefore, the determination of the coefficients σ and k as a function both of the various levels of safety risk and the number of employees allows to determine the increase of the total cost to implement OHSAS standard.
The final relation is given by the following Equation (2):

$$CT' = CT^* \sigma^* k \quad (2)$$

For case study under study the CT is estimated considering:

- Level of safety risk: Low = 1
- Number of employees: 25 = 1

The estimated CT is shows in Table 5

Table 5: Annual Costs - estimate

Costs	€ (euro)
OHSAS Implementation costs	9.746,00
Human Resources costs	8.514,00
Certification costs	3.718,00
total	*21.978,00*

While if we consider, as an example, a company with:

- Level of safety risk: Medium = 1,5
- Number of employees: 110 = 1,8

The estimated CT' is 57.450,00 €.
The variation is given by

$$\Delta CT = CT' - CT \quad (3)$$

Thus, in the example the ΔCT is 35.472,6 €. Thus, the cost increase is about 60%.

3.5. Monitoring

It is estimated that an injury to the company costs 5 times more than a non-injury. Furthermore, it is estimated that 1 € invested in safety costs ensure 2.2 € in benefits. Benefits include all reduction in risk to workers and to the wider community, such as avoidance of deployment of emergency services and avoidance of countermeasures such as evacuation and post-accident management.

4. DISCUSSION

The goal of implementation of OHSAS is to meet client's requirement and to improve safety and health in both the segments. Thus, it is essential to monitor KPIs over the time. Table 6 shows the set of monitored KPIs.

Table 6: Monitored indicators (%)

KPIs	Last Year 2015	Target 2014	Actual 2016 (I sem)
R1	30	20	50
R2	20	25	18
R3	15	18	7
T1	35	30	40
T2	20	20	15
T3	10	15	10
C1	21	30	25
C2	15	15	10
M1	10	5	8
M2	5	7	5

While Figure 5 and Figure 6 shows an example of monitored KPIs.

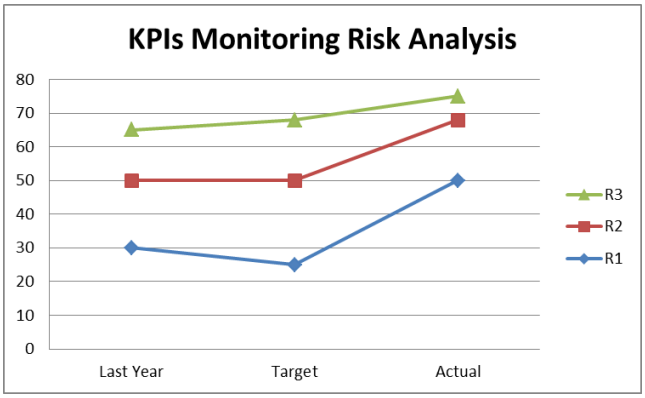

Figure 5: Example of monitored indicators for Risk Analysis

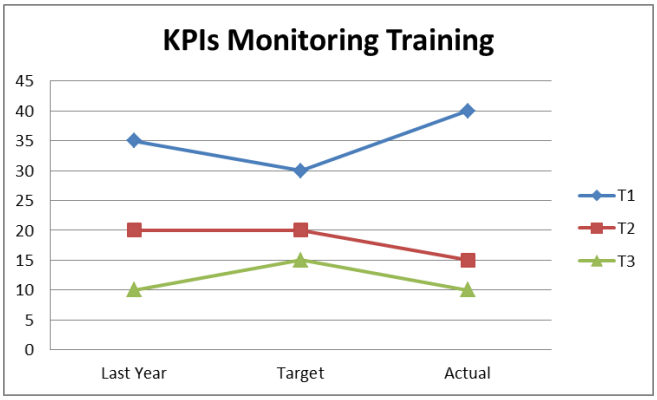

Figure 6: Example of monitored indicators for Training

5. CONCLUSION

The necessity of evaluating the OHSAS standard implementation within an organizations by means of a simple and flexible method has been the main focus of this work. It is important to emphasize the method validity. Its application is worthy as for the diagnosis of the organization performance and contribute for the decision making process, having as objective the continuous improvement of its processes and of the implemented management system.

The results presented demonstrated that the proposed method is an efficient tool to diagnose, in a simple and flexible way, the performance of an organization that implemented or is implementing a quality, environment and occupational health and safety management systems with the purpose of improving the performance of its internal productive processes or of administrative support.

The proposed set of KPIs should be tailored to specific conditions of a company, such as the size, industry sector, types of occurring hazards, or the maturity of safety management processes. The advantages of the model are: 1) Provides a structured approach for managing safety; 2) Existence of a continuous improvement culture and 3) Reduction in incident levels with increased measures of performance.

Future work will focus on soliciting opinions from more experts and testing the validity of this model in other industrial sectors. The ultimate goal is to develop a comprehensive model for all industrial sectors.

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