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A System of Quality, Safety, and Environment Integration based on QFD and Risk Approaches

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Under the pressure of globalization and competition, the companies use more and more quality, safety and environment process management and certifications. Several practices of quality, safety and environment can be observed, but all of these are distinctly established.

Currently, there is no repository for the Integrated Management System (IMS). Companies must rely on repositories of three management systems: Quality, Safety and Environment, which can cause contradictory situations and redundancy in terms of actions of improvement.

At the international level, several standards were introduced but they remain very complex to implement. Consequently a need in terms of methodology is imperative. For that purpose, we have proposed a methodology of integration of quality, safety and environment by taking into account the correlations between the three systems. So, the plan followed in this research involves presenting the models and existing theories through the literature review, then suggesting the developed methodology, and finally exposing the test of this methodology through a case study.

Keywords: Integrated Management System (IMS), Continuous improvement, Risk Management, Quality Function Deployment.

1. Introduction

In the current demanding situation of aggressive and constantly developing competition and in the context of sustainable development, companies should now take into account sets of factors relating to quality, safety and environment (QSE).

This cannot be done without the juxtaposition of several systems, which is difficult and complex, and can lead to contradictions and inconsistencies or poor visibility goals. Several areas of management have been formalized, precisely to meet the needs of managers and help them review their organization and management practices. And many models of integration approaches were proposed. However, these approaches and analysis remain theoretical and difficult to implement. New methodology needs to be proposed in order to facilitate, to managers, the implementation of an integrated management system methodically. It will seek the sustainability of business development because the QSE management has now become a strategic priority for the enterprises.

In the present work, we will present, firstly, the various theoretical approaches of the integrated management system of quality, safety, and environment. Secondly, we will present an implementation process methodology of an integrated system and finally, conclude with a case study realized in a company.

2. Literature Review

2.1 QSE Integration Approaches

Several approaches of QSE integration allow the fusion between the three management systems, quality, safety and environment.

Firstly, we observed the Plan, Do, Check, Act (PDCA) logic which constitutes one of the pillars of all management systems and allows it to be dynamic instead of static, and constantly improving. This finding is also confirmed by Savino and Mazza (2014), who explain how integrated environmental and continuous quality improvement can occur through a practical implementation of PDCA cycle.

Secondly, the risk management approach was observed, as it has been used for OHSAS 18001. Indeed, the approach to risk assessment represents a major axis of similarities found in the logic of integration of management systems. Leaders must manage and most importantly, assess. To do this, they must be identified and minimized. Any economic activity generates risks. According to Alena Labodova (2004), this integration methodology based on risk management is done in seven stages:

1. Description of the production system and its environment;
2. Identification of sources of danger and possible target systems;
3. Combinations of scenarios and identification of possible actions;
4. Risk assessment in terms of probabilities and consequences;
5. Implementation of the objectives;
6. Definition of means of prevention;
7. Management of human, financial and material resources to achieve the planned objectives.

Risk management must involve all company procedures. Thirdly, a survey conducted in Spain by Simon.A, Karapetrovic.S, Casadesus.M (2012) shows that the analysis of common elements of standards and process map are the most common methods used during the integration process.

Also, Savino, M, Brun, A and Riccio C (2011) get an integrated method to support maintenance management considering both the desired performances and the personnel safety requirements, by merging the failure mode effects and criticality analysis approach (FMECA) and the risk evaluation into a unified procedure. This approach uses a fuzzy inference engine to define certain key indices related both to production performance and safety level.

In addition, there exists a notion of generic processes, a new concept that supports and facilitates the integration of systems, as confirmed by Harmand and Eckl (2007). This model supports various management systems related to quality, environment and safety. This model provides the company with sufficient flexibility to incorporate different types of requirements in a single system. The generic processes, as defined by Eckl (2004), are:

- Responsibility, Commitment and Leadership;
- Conception / planning;

- Resource management;
- Realization;
- Measures, Audits and Reviews;
- Analyses / studies;
- Corrective and preventive improvement.

The final point is the degree of integration of each process, because there is no single way to integrate QSE process for all companies, but each company has its specificity and its characteristics. That is why we have found through our reading that there are several levels or degrees of integration.

Seghezzi (1997) describes three "different paths to system integration: adding, merging and integration." For "addition", the sub-systems for quality, environment and safety, are kept separate," described in separate documents". For "fusion", work instructions are fully integrated, but not the procedures, and the manual "total system is created, but the subsystem is still visible." For "integration", companies can choose or develop a generic management system as their general system and include all sub-systems.

Wilkinson and Dale (1999) describe a four-level model. The first level "applies to individual MSs, where the system is integrated into every function and activity" of the organization. The second level is a combination of "systems based on the identified linkages between MSs". Documentation is combined and "integration into every function is still required". The third level "involves integrating selected parts" of MSs "with other certificated systems, but without using identified linkages". The fourth level "is to integrate both certificated and uncertificated systems with the overall MS", with the policies and objectives "aligned to and supporting the overall strategy, policy and objectives of the business."

Kirkby (2002) proposes an approach that has three main models of integrated management systems. The first level is "separation" where the systems are independent; the second is "alignment" in which different systems may have common points such as internal audit and management review. The third level is the "integration" which combines all the systems into one common system.

For Karapetrovic (2002), there are three degrees of integration: those which have integrated only documentation, those which have aligned processes, objectives, and resources and finally those which have integrated all parts of management systems in a single management system.

The main conclusion that can be drawn from this literature review is that the question of integration has been approached by several authors using different methods.

However, according to these related works, we notice that there is a need in terms of methodology because all the presented approaches are general and constitute more logics of reasoning than practical methods that can be used in enterprises to integrate the three management systems: quality, security and environment. Consequently, we are going to propose a methodology of integration by taking into account all the elements mentioned in the literature review.

The proposed methodology is based on the Quality Function Deployment and risk approaches, in order to consider all the relationships and correlations between the three systems.

2.2 Quality Function Deployment

Quality Function Deployment (QFD) is a structured process that provides a means to identify and carry the voice of the customer through each stage of product/process development. As part of the QFD process, the customer and engineers benchmark both their product and process relative to the competitors to help determine the target value, which results in bringing product to the market faster and cheaper, as mentioned by Sekhari and Gien (2001).

QFD deals with verbal data and uses many charts to discover interrelations between customer demands, product characteristics, and manufacturing process. The first chart or matrix, known as the House of the Quality (HoQ) due to its house shape (Figure 1), forms the basis of any QFD project.

QFD is attracting a lot of attention in several industries. It is increasingly being recognized as an excellent means of ensuring that the voice of the customer (VOC) directs the efforts of the complete organization. It is well documented that the use of the QFD can reduce the development time by 50% and start-up & engineering costs by 30%, as explained by Sekhari and Gien (2001).

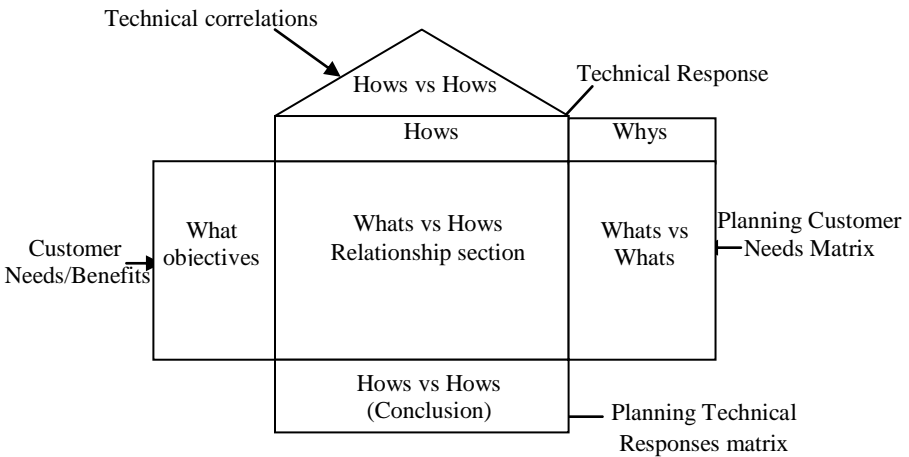


Figure 1 *The House of Quality (HoQ)*

2.3 Risk Approach

For the direct implementation of an Integrated Management System (IMS), a methodology based on risk analysis was chosen. Risk can be used as an integrating factor—risk for the environment, risk for life and health of employees and surrounding population, and risk of economic losses as mentioned by Danihelka (2001).

From Labodova's perspectives (Labodova, 2004), the same source of hazard can cause risks to targets in more management areas, for example non-compliant products production. A decrease of non-complying production means:

- Reduction of the risk for losses because of rework or scrap;
- Reduction of the risk of bad quality products' delivery to customers;
- Reduction of the risk for environment (decreased consumption of raw material and energy, decrease of waste generation);

- Reduction of the risk for employees (as processes are better understood, the probability of accidents will also be reduced);
- Reduction of the risk for consumers (non-compliant product can be a source of accident/injury).

3. Methodology of Integration Based on QFD and Risks Approaches

The proposed methodology aims at defining the QSE actions which answer to the quality, safety and environment needs in a correlated way and without incoherence.

3.1 Methodology Principles

In this methodology, we combined these four principles:

1. **The Process Approach:** Strongly advanced by the ISO 9001 standard, the process approach is a tool of quality management which consists in describing methodically a company, by a set of process.

Faucher (2007) suggests that it can be interesting for the company to have a global process approach by integrating the listening of needs and expectations of all the interested parties with the consideration of the quality, safety, and environment aspects.

In an integrated management system, it is a question of modeling the process map of the company by representing set processes relative to the quality, the safety and the environment and their interactions in a global vision.

2. **Risk Management:** In an integrated management system, the risk can be defined as: “a sudden or deferred event which can pull a non-satisfaction of needs and waits of one of the interested parties”, according to AC X 50-200, Afnor (2003).

The analysis of the risk can be led basing on the process approach. It has to take into account all the consequences of the interested parties.

3. **The Principle of the deployment of the QSE needs and risks based on QFD:** We were inspired by the method of Quality Function Deployment (QFD) developed by Akao (1993). This method allows bringing continuous improvements to the defined QSE needs.

4. **The Principle of the continuous improvement, guaranteed by the iterative deployment principle of the QFD method matrices:** We identified the most important QSE actions of our integrated management system. The principle of the continuous improvement is based on three systems:

- For the quality management system, it is the continuous improvement of the processes, the organization and the management system to control its processes and increase the customer satisfaction;
- For the environment management system, it is the improvement of the environmental performances;
- For the safety management system, it is the improvement of safety by managing all the risks.

3.2 Methodology Steps

We organized our methodology in 3 phases described in 6 steps:

This first phase of our methodology is the process approach and risk analysis that contain 3 stages:

1. Identification of the processes;
2. Identification of processes' needs and risks.
3. Evaluation of the risks.

The second phase is the deployment of the QSE needs and risks:

4. Deployment of the QSE needs to QSE actions;
5. Deployment of the QSE risks.

And the third phase is the continuous improvement:

6. Interpretation of the impact factor of the QSE integrated actions.

Figure 2 presents the phases and the steps of the methodology:

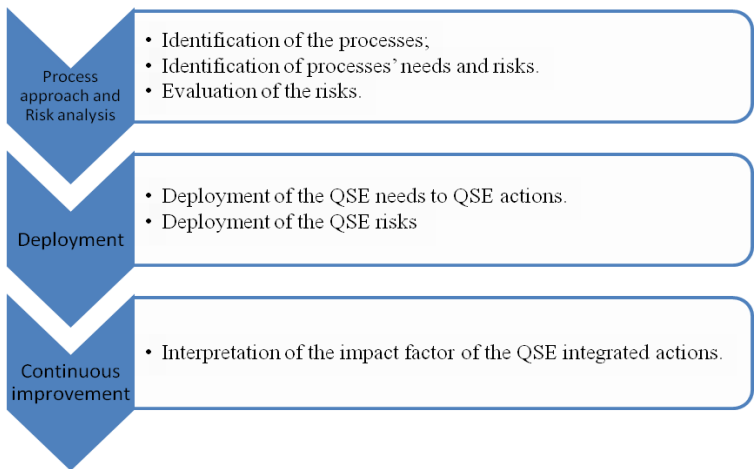


Figure 2 Phases of the Proposed Methodology

3.2.1 Phase 1: The Process Approach and Risk Analysis

After identifying all the business processes and their quality, safety and environmental interactions, comes the stage of identification of needs of the company and customer expectations.

The three domains, quality, safety and environment, answer the needs of the customers:

- The quality to those of the external customer.
- The safety to those of the internal customer.
- The environment to the customer as citizen.

However, the question that can be asked is how to ensure that quality needs do not compromise safety and environment needs and conversely. We start by constructing a process/ needs matrix for every management system separately. These matrices will allow us to analyze the relations between processes and needs related to every process and to establish the correlations between these needs. After that, we calculate the importance of needs related to the three systems.

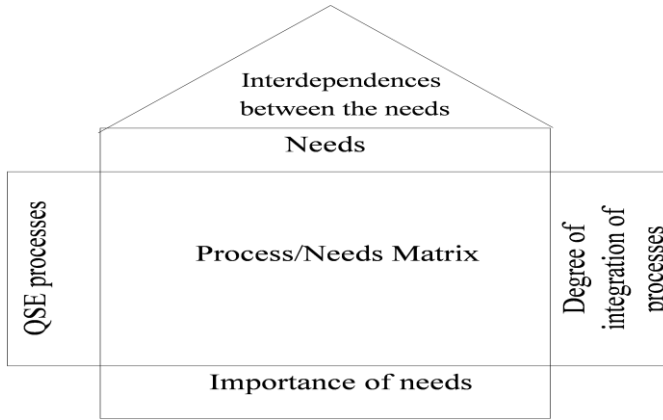


Figure 3 Process/Needs Matrix

The degree of integration of the process (PID): It represents the relative impact of every process on our QSE system, ranked according to balanced coefficients that can be determined by the company.

The relations processes/needs: The expression of the correlations takes the shape of symbolic conventions. We identified three types of correlations: a strong correlation, an average correlation and a low correlation. We represent them successively by: Δ , \odot , \ominus . After that, valuable balances are used to quantify each of these symbols. The scale (1, 3, 9) quantifies for a relation (low, average, strong).

The interdependence between the needs: In the same way, we have to highlight the correlations between risks, and specially the conflicting relations. By getting inspired from the classic QFD approach, we identified four degrees of technical impact: ++ strong positive impact; +Average positive impact; < > No impact; - average negative impact; -- strong negative impact.

The importance of a need “j” (IMP (N_j)) is calculated by the following formula (1):

$$IMP(N_j) = \sum_i \left[(PID)_i \times \text{correlation}(\text{process}_i / \text{need}_j) \right] \quad (1)$$

The calculation of the importance of every need allows us to determine the priority needs which present a strong QSE correlation.

To control our QSE processes, it is necessary to integrate the risk management in our approach. The risk assessment constitutes a crucial stage of the approach of prevention of the contradictions and the incoherence which can exist in our integrated system. We begin with the identification of the technical, human and organizational risks as we find in the ISO 31000 standard, then we would proceed to the analysis and the classification of these risks. The risk assessment must be regularly renewed.

The evaluation of risks is done by calculating a score (S) according to three parameters: the frequency of the risk; the gravity; and the possible consequences.

$$S = \text{frequency score} \times \text{gravity score} \times \text{possible consequences score} \quad (2)$$

Scores of the three parameters vary on a 1 to 5 scale according to the importance of the parameter. After that, we placed the major QSE risks and the process, identified in the previous stage, in a (Process/Risks) matrix and establish the relations and the correlations.

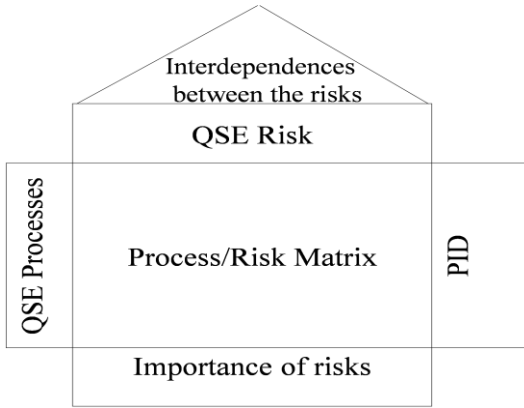


Figure 4 *Process/Risks Matrix*

Then, we calculated the importance of the risks by using the formula (3):

$$IMP (R_j) = \sum_i \left[(PID)_i \times \text{correlation} (process_i / risk_j) \right] \tag{3}$$

By taking into account the score of every risk, we determined the risk coefficient $Coef (R)$ obtained by the following formula:

$$Coef (R) = S(R) \times IMP (R) \tag{4}$$

This risk coefficient indicates the factor risk of every process by taking into account correlations between the QSE processes, to determine the most critical processes.

3.2.2 Phase 2: The Deployment of QSE Needs and Risks

At first, we established the (Needs / Actions) matrix as illustrated in Figure 5 which allowed us to calculate the importance of every action related to the needs $IMP(A/N)$, so that the capacity of every QSE action to answer to the QSE needs could be estimated.

Secondly, we established the correlations between these QSE actions and the risks identified and evaluated in the first phase of our methodology. So that we could be sure that our QSE actions contributed in reducing all the risks without incoherence. We established the (Risks/Actions) matrix (Figure 5):

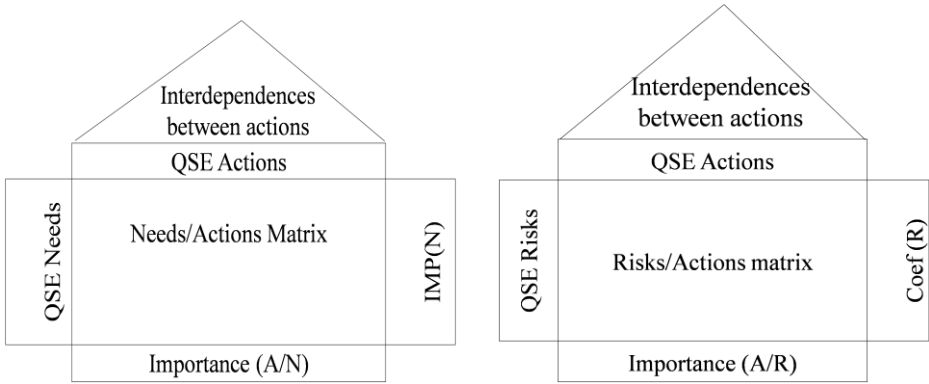


Figure 5 Needs/Actions Matrix and Risks/Actions Matrix

The importance of the action ‘j’ related to the risks IMP (Aj/R) is calculated by the following formula:

$$IMP(A_j/R) = \sum_i \left[Coef (R_i) \times \text{correlation} (risk_i/action_j) \right] \quad (6)$$

This would allow us to identify the QSE integrated actions which meet the expectations of the three management systems, quality, safety and environment, by taking into account the risks of our integrated system.

3.2.3 Phase3: Continuous improvement

From the obtained results, we deduced the impact factor (IF) of every QSE action by the following formula:

$$IF(A) = IMP (A/N) \times IMP (A/R) \quad (7)$$

This factor indicates the level of the impact of every action on our QSE system by taking into account the QSE needs, the QSE risks and the existing correlations and interdependences between the three management systems, quality, safety and environment. Once the identified QSE integrated actions are implemented, we can exceed a level of risk, to reach expectations of the customer and join the process of continuous improvement. This is because all the management systems are based on the principle of the continuous improvement.

The following schema represents the global architecture of the proposed methodology:

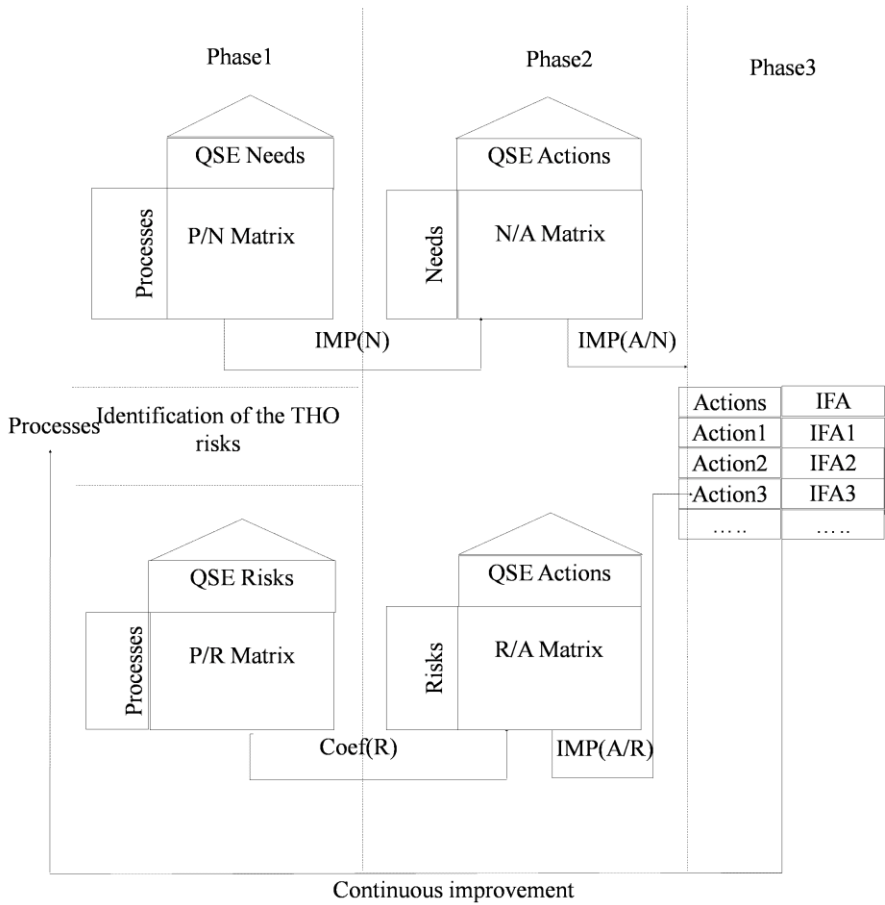


Figure 6 Global Architecture of the Proposed Methodology

4. Case study

In order to validate the suggested methodology, we tested it in a Moroccan industrial company. The tests concern particularly business processes of the company because they are the ones which have the most significant and important degree of integration.

4.1 Results

After analyzing the process map of the company and identifying the QSE processes and needs, we deployed our methodology. We established the first matrix (Figure 7) in order to identify the QSE needs and their correlations.

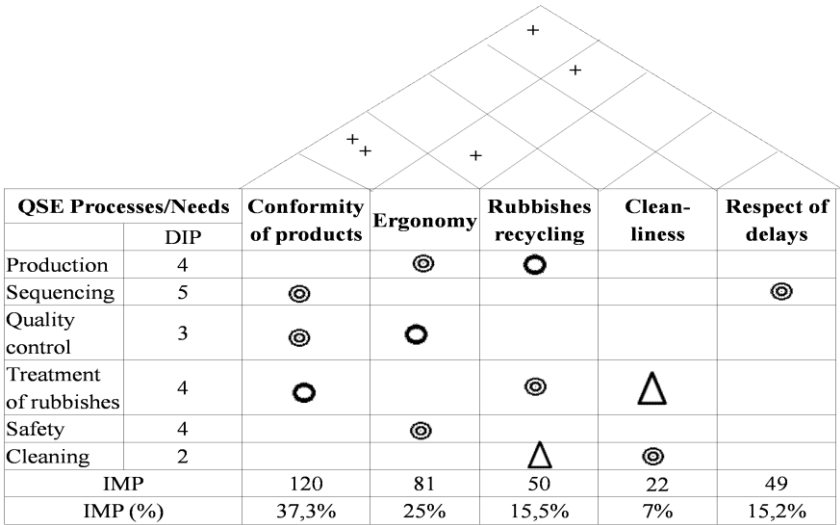


Figure 7 QSE Processes/ Customers' Needs Matrix

After that, we determined the risks for each process and evaluated as explained previously. Figure 8 presents the correlations between QSE processes and QSE risks and calculates the risk coefficient by Formula 4.

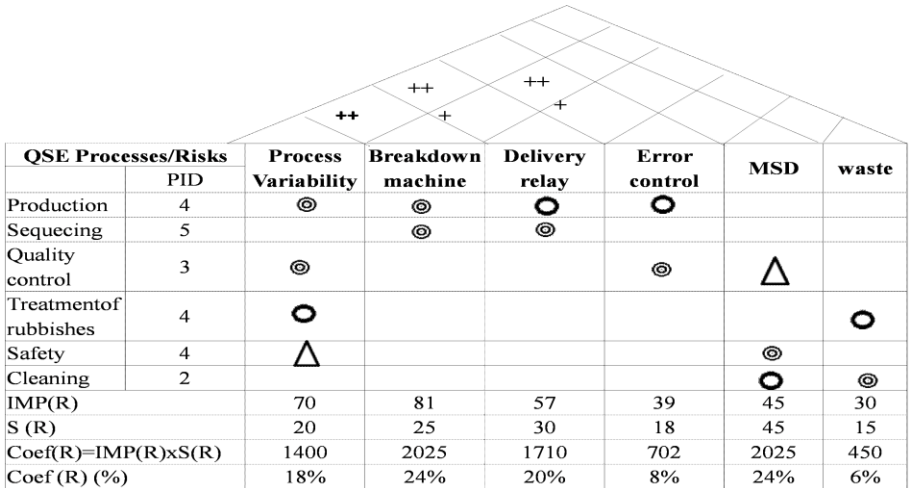


Figure 8 Processes/Risks Matrix

In the second phase of our methodology, we deployed the QSE needs to QSE actions and established the correlations in order to be sure that quality needs do not compromise safety and environment and inversely. The results of the needs/actions matrix are presented in Figure 9.

Needs/QSE Actions							
	IMP	SPC	Preventive Maintenance	Ergonomic study	Recycling rubbishes	5S	Scheduling
Conformity of products	37,3	⊙	⊙	⊙	○	△	
Ergonomy	25		○	⊙		○	
Recycling	15,5				⊙		○
Cleanliness	7					⊙	
Respecting deadlines	15,2	○	○				⊙
IMP(A/N)		381,3	458,1	567,7	251,4	175	183,3
IMP(A/N) (%)		19%	23%	28%	12 %	9%	9%

Figure 9 Needs/Actions Matrix

In this same phase, we established the correlations between the QSE risks and the QSE actions (Figure 10), to verify the coherence of our integrated system.

Risks/QSE Actions							
	Coef(R)	SPC	Preventive Maintenance	Ergonomic Study	Recyclage of Rubbishes	5S	Scheduling
Process Variability	18%	⊙	○	○	○		△
Breakdown machine	24%		⊙				○
Delivery delay	20%						⊙
Error of control	8%	⊙	○	△			
Ergonomic disorder	24%	△		⊙			
Rubbishes	6%				○	⊙	
IMP(A/R)		258	294	278	72	54	270
IMP(A/R) (%)		21%	24%	23%	6%	4%	22%

Figure 10 Risks/Actions Matrix

Finally, we combined the results obtained in the needs/actions matrix and the results of the risks/actions matrix by using Formula (7). Then, the impact factors of the QSE

actions were calculated. The results are presented in Figure 11 to visualize better, the most urgent QSE actions.

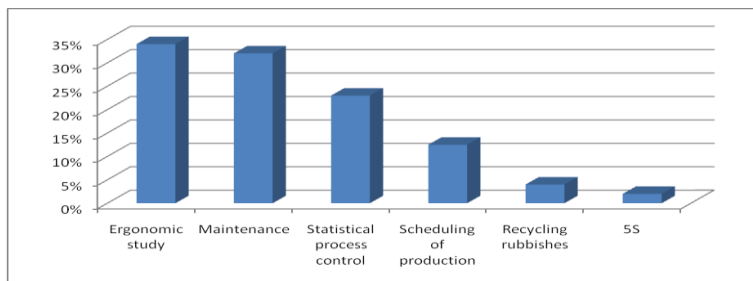


Figure 11 Histogram Representing Impact Factors of QSE Actions

4.2 Interpretation of the Results

According to the obtained results, it is noticed that the integrated action to implement first is an ergonomic study of the operations realized by the operators because this has an important impact on the variability of the process and engenders ergonomic disorders (Figure 10) and it answers important needs as conformity of products and ergonomic with strong correlations as we can see in the needs/actions matrix (Figure 9). This action influences also the safety aspect as illustrated in the matrix. The following two actions that have an important impact factor are maintenance and statistical process control (SPC). These actions have impacts on the three management systems: quality, safety and environment simultaneously. In addition, the methodology allows to see the degree of the impact in terms of risk and needs for the QSE integrated system. This approach permits to merge the three management systems into an integrated system with unified answers. This will allow, to integrate afterward, a process of QSE continuous improvement. We notice that this methodology constitutes not only a tool of integration of three management systems: quality, safety and environment, but also a decision-making tool to allow us to identify the QSE actions.

The implementation of the proposed methodology shows that it is in line with the approaches presented in the related work. This methodology combines the principle of PDCA approach as proposed by Savino and Mazza (2014), the process map as explained by Simon.A, Karapetrovic.S, and Casadesus.M (2012) that we used for the identification of the processes in the first phase of our methodology, and the risk management as proposed by A. Labodova (2004).

This combination represents the added value of the proposed methodology because it guaranteed to eliminate incoherence or redundancy by taking into account all the correlations which exist between the three studied management systems in terms of needs and risks.

5. Conclusion

Today, the implementation of an integrated management system is the main pillar for an approach of sustainable development in companies. In this frame, we proposed a methodology of integration of the quality, safety and environment concepts based on three stages: the process approach; the analysis of needs and QSE risks and continuous improvement. The main advantages of this method are:

- Bring a unique answer to customers' quality, safety and environment needs in terms of actions to deploy;
- Take into account needs and expectations of all interested parties;
- Avoid redoing tasks, common to three systems of management and save time.
- Avoid contradictory actions susceptible to alter the image of the company.

The benefits mentioned here are in line with the benefits found by authors like Simon.A, Karapetrovic.S, Casadesus.M (2012):

- Task simplification (documentation, requirements)
- Increase of organizational efficiency;
- Better use of the internal and external audit results;
- Firm image improvements.

There is, however, an element used in our research which differs from what we find in theoretical literature, i.e., the proposed methodology starts from needs of internal and external customers and their correlations with processes. These correlations guaranteed customer's satisfaction which is the basic principle of quality, safety and environment systems. In addition, we noticed that the integration of management systems evolved spontaneously into an integrated and unified system, by using the developed methodology.

Finally, the main conclusion that can be highlighted from the findings is that the proposed methodology can be used as practical method to integrate quality, safety and environment. This methodology was tested in practice and no conflicts with theory were found. This approach can be used in any kind of company. For bigger companies, with more complicated production systems, it is useful to have an expert on quality management and risk evaluation methods in the implementation team. Many quality and risk evaluation methods demand special training to be applied properly. This methodology was thought for any kind of company but was implemented only in industrial companies. It should be tested within a large variety of firms.

From the perspectives of this work, it would also be interesting to use this methodology to integrate quality, safety and environment with other management systems. A future work may extend the developed methodology in order to make it suitable to other domains of management.

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