CLASSIFICATION OF RISK ACCEPTABILITY AND RISK TOLERABILITY FACTORS IN OCCUPATIONAL HEALTH AND SAFETY

Abstract

Risks are omnipresent in most human activities. Risk analysis helps to establish the level of risk of a given situation, and to determine if the risk is acceptable, tolerable or unacceptable. At this stage, the consideration of individual or societal factors becomes very important in the decision-making process regarding the acceptability or the tolerability of a risk. In the occupational health and safety (OHS) field, these factors are often implicit and poorly defined. In this work, the risk acceptability influential factors in the domain of OHS are indexed, and a typology of these factors is suggested. In total, 8 parameters regrouping 19 criteria and 14 variables that influence the risk acceptability process are presented, and their scope in OHS is discussed.

1 INTRODUCTION

1.1 Risks

Risks are omnipresent in most human activities, and there are studies conducted with the purpose of assessing and comprehending risks in almost all disciplines. Both human science and applied science have actively addressed this topic, generating a broad diversity of concepts related to risks.

Generally speaking, the notion of risk allows to put human efforts in perspective regarding their capacity to prevent and protect themselves against harmful events, whether they result from natural causes or human activities. According to the Standard ISO 3100 (2009) *Risk management – Principles and guidelines*, a risk is the effect of uncertainty on objectives; it is the unknowable aspect of the risk that lies in the succession of elements that are not fully controllable (Deroches, et al. 2003). Moseman (2012) defines the risk as the quantification of economic and human losses in terms of the likelihood of an incident to happen and the importance of the damage. Woodruff (2005) suggests that a risk is the possibility that an individual or something of value is affected by a hazard. Regarding machine safety, a risk is defined as being the combination of the severity of a potential damage and the probability of this damage to occur (ISO, 2010).

Risks often have a limit that is not well understood, but that can be defined using risk management methods. These methods generally aim at analyzing the risks, i.e. identifying and assessing their severity, in order to inform decision-making processes towards the mitigation of the risk to an

acceptable or tolerable level (ISO, 2010). At this stage, the consideration of individual or societal factors becomes very important in the decision-making process regarding risk acceptability or tolerability. This process is complex and blurred, but it is implemented anyway on a daily basis by managers and engineers all around the world.

1.2 Risk Acceptability and Risk Tolerability

The assessment of the level of severity of a risk allows to determine if this risk is acceptable, tolerable or unacceptable. In the literature, however, there is a certain ambiguity regarding the definition of the acceptable risk and the tolerable risk. Indeed, for numerous authors, the terms "acceptable risk" and "tolerable risk" are seen as synonyms (Main, 2004). Nevertheless, the UK's *Health Safety Executive* (HSE) establishes, in a certain extent, the difference between the two concepts: *"'tolerable' does not mean 'acceptable'. It refers instead to a willingness by society as a whole to live with a risk so as to secure certain benefits in the confidence that the risk is one that is worth taking and that it is being properly controlled"* (HSE, 2001). According to Schjølberg and Østdahl (2008), the tolerable risk always refers to the acceptable risk, and the acceptability of a risk would represent a subset of the risk tolerability. These authors define the tolerable risk as an "accepted" risk in a given context, depending on the existing values in the society. As for Finlay and Fell (1997), they suggest that a risk can be tolerated , and hence lived with, without necessarily fundamentally being accepted.

In the context of this article, the following definitions are proposed to distinguish the concepts of acceptable risk and tolerable risk: the "acceptable risk" is a risk that is worth taking based on the expected benefits, and for which the efforts invested in finding new ways to reduce it are marginal or nonexistent. The utilization of a kitchen knife can be a good example. As for the "tolerable risk," it consists in a risk that is worth taking based on the expected benefits, but that remains under surveillance, and for which attenuation means continue to be sought. For instance, measures allowing to mitigate the risks emanating from driving have been proposed for decades. It is how the safety belts, the air bags, the ABS brakes, the collision avoidance systems, etc., have been introduced.

According to those definitions, the acceptable risk constitutes a subset of the tolerable risk. Both concepts imply the decision to admit that a risk is sufficiently "low" or "controlled" in a given situation, by taking into account the laws, the values, the culture, and the context of the environment or society in which one find itself. Moreover, in order to simplify the text, the notion

of risk acceptability will be used indistinctly in the remaining of this article to talk about both concepts.

1.3 The General Principles of Risk Acceptability

Risk acceptability is a judgment that takes root in the perception of the risk, even if the perception of the risk is a complex variable in the extent where it varies according to the societies and individuals involved. The HSE (2001) suggests three fundamental criteria in the judgment of the acceptable or tolerable risk: the equity-based criterion, the utility-based criterion, and the technology-based criterion. These are in fact ethical reasoning principles that allow to lay the basis of the risk acceptability decision-making process.

The equity-based criterion is based on the fact that all individuals have a right to a minimal protection. It is a moral and ethical reasoning that is materialized by a maximal limit that cannot be crossed in order to ensure a minimal safety to everybody. Vanem (2012) also focuses on the ethical aspect, and claims that fair actions versus bad actions and good values versus bad values consist in the basis of a good ethical judgment. The equity-based criterion defines somehow the red zone that should not be crossed, no matter what the expected benefits are.

The utility-based criterion is based on the relation between the expected benefits of the risk attenuation measures and the costs related to these measures. It consists in determining if the benefits resulting from these measures, whether on the chapter of human lives saved or in economic terms, are worth the required investment.

The technology-based criterion stipulates that the level of the acceptable risk or the tolerable risk is reached when the rules of practice in the field are respected. Abrahamsen et al. (2013) claim that this principle can be accomplished through the utilization of best practices, for instance, standards and professional codes of practice. Nonetheless, best practices remain quite a vague concept due to the variety rules and the differences found from a country to another. However, this gap is more and more filled with the alignment and the quasi-globalization of these rules through international standardization. The standards, even though written by different organizations, usually inspired one another, and hence share common basis. Nevertheless, it is important to note that this principle can lead to ignoring the costs related to complying with all the proper rules.

The cost-benefit notion is actually a fundamental principle in most of the approaches linked to risk acceptability. To what extent can the benefits generated counterbalance the potential negative

consequences of the risk to the point of being considered acceptable? Cost-benefit is hence an element that cannot be completely dissociated from the perception of the risk (Hergon et al. 2004). According to French et al. (2005), the costs linked to a risk can be divided in three parts, i.e. (i) the costs linked to safety (implementation of risk reduction measures); (ii) the costs linked to the impacts of the risk on the workers (professional diseases and accidents); and (iii) the costs linked to the consequences of the risk to the public.

The cost-benefit analysis needs to lead towards a balance between the costs (current or potential) and the benefits associated with the decision made regarding the acceptability or the tolerability of a risk (Jones-Lee and Aven, 2011). Consequently, the cost-benefit analysis becomes a necessary tool in the decision-making process, and ensure avoiding major disparities. Moreover, it provides a useful approach to compare different options, as well as the related risk reduction measures. The assessment of the monetary value of the non-financial consequences of the risk, for instance human life losses or environmental damage, remains, however, an issue within the cost-benefit notion (Aven, 2009).

1.4 The Main Approaches of Risk Acceptability

In the literature, there are many models or approaches that allow to define the limits of risk acceptability or risk tolerability. The ALARP approach – *As Low As Reasonably Practicable* (Figure1) seems to represent the most widely known and studied approach (HSE, 2001). Abrahamsen et al. (2013) consider this approach as vital in the identification of the proper methods aiming at reducing risks.

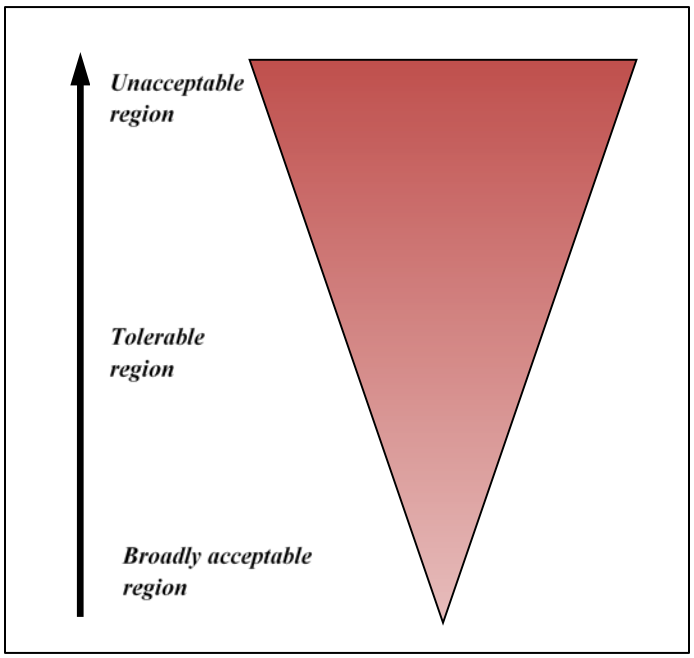

Figure 1: ALARP approach (Source: adapted from HSE, 2001)

According to this approach, there is an unacceptable level of risk, no matter what the expected benefits are (*Unacceptable Region*). Within this zone, taking the risk cannot be justified, regardless of the reasons. Under this unacceptable zone, there is the *Tolerable Region*, where risks can be tolerated depending on the benefits that could be derived. Within this zone, the risks are tolerated if they cannot be more attenuated or if the costs of implementing risk reduction measures are excessive or disproportionate compared to the benefits expected from this measure. Consequently, as part of the ALARP approach, the costs associated with the reduction of the risk need to be taken into account (Vanem, 2012). However, as Jones-Lee & Aven (2011) highlight it, "*The test of what is (reasonably practicable) is not simply what is practicable as a matter of engineering, but depends on the consideration, in the light of the whole circumstances at the time of the accident, whether the time, trouble and expense of the precautions suggested are or are not disproportionate to the risk involved, and also an assessment of the degree of security which the measures suggested may be expected to afford."* Under the tolerable zone, lays the *Broadly Acceptable Region*, within which the risk is considered acceptable: it is so low that it is unlikely that a further reduction of the risk is profitable.

The ALARA approach (As Low As reasonably achievable) is similar to the ALARP approach. It was initially used in Europe to assess the radiation risks, as well as the therapy through radiation for which the exposure limit values are not well known (Johansen, 2010; Ale, 2005).

The GAMAB approach (*Globalement Au Moins Aussi Bon*, in French) was developed in France within the rail transportation industry, and is increasingly taken into account in other sectors (Schjølberg & Østdahl 2008). This approach is based on the principle that any new system should be at least as safe as the pre-existing one. This approach is essentially technological and uses the pre-existing system as a baseline (Johansen, 2010). Hence, the present safety level becomes a minimal requirement. Another version of the GAMAB called GAME (*Globalement Au Moins Équivalent*, in French) is generally used to analyze new activities by comparing the known risks of a baseline activity to those of the new activity (Vanem, 2012). The GAME is also done by comparing the risk history contained in databases.

The MEM approach (Minimum Endogenous Mortality) is mostly used for the safety of technical facilities. The term *endogenous mortality* refers to a death due to internal causes, for example a disease or aging, as opposed to the term *exogenous mortality* that is a death caused by external factors such as accidents. This approach uses the number of natural deaths as a point of comparison to establish the acceptable level of risk of a given situation (Johansen, 2010). For instance, on this basis of this approach, the number of consecutive deaths due to technological accidents should not be higher than the probability of a 15-year-old teenager to die, for which the average number of consecutive deaths resulting from natural causes in a developed country population do not exceed 10^{-4}/year (Schjølberg & Østdahl, 2008).

1.5 Influential Factors of Risk Acceptability

In addition to the principles and approaches previously indicated, many influential factors impact risk acceptability. These factors, or criteria used to establish if a risk is acceptable or tolerable, are numerous, and many works have focused on this question, namely Vanem (2012), Lind (2002a,b), Ditlevsen (2003), Henselwood & Phillips (2009), and Huang et al. (2013). These factors can differ depending on the countries, the social and organizational cultures, or the industries.

Lind (2002a) suggests a list of some influential factors implied in the process of deciding whether a risk is acceptable or not. These are ethical, economic, political, and psychological factors. In his subsequent works, Lind (2002b) proposes that the risk acceptability process also takes into account the financial benefits generated; the social, environmental, and cultural considerations; and the ability to reduce the number of accidents. To this, can be associated moral, emotional, and sociocultural judgments that may influence them in many ways. Hartford (2009) completes this list by adding the historical legacy, and the socioeconomic, political and legal context. Finally,

the risk acceptability process is linked to time and inherent situations, in addition to the consideration of the associated costs and benefits (Johansen, 2010).

For a given industry, identifying the risk acceptability factors remains complex (Wenping & Xia 2012). The identification of these factors implies considering, among other things, the type of risk, the safety objectives to be reached, as well as the data available regarding different accidents involving this risk (Rodrigues et al. 2011). It also depends on the individual, societal, economic and environmental impacts of the risk. Moseman (2012) suggests two approaches aiming at identifying the risk acceptability criteria in a given context. In a speculative manner, they can be determined according to the current, historical or estimated levels of risk in similar contexts. They can also be established by comparing them with other societal risks in general. In the context of this study, the basis of those two approaches has been considered in order to identify and classify the risk acceptability influential factors in OHS.

1.6 Objectives of the Study

In the field of occupational health and safety (OHS), the risk acceptability influential factors seem less known; they are rather implicit and poorly defined. The literature is actually relatively lean regarding the specific factors in this area. Employers and workers are hence often obliged to resolve the dilemma regarding accepting or refusing a risk based on more or less explicit criteria. Without always realizing it, they sometimes accept precarious situation, often without being able to objectively justify the grounds for their decisions.

These ambiguous situations can have scientific bases that can be interesting to look at. The underlying question of this study is hence the following: what are the influential factors that impact the decision to accept, tolerate or refuse a risk in OHS, and how are those factors interrelated? The objectives of this study were then to index the risk acceptability influential factors involved in the field of the OHS, and to suggest a typology to classify these factors.

The next section of this article presents the methodology used to meet these objectives. Sections 3 and 4 show the results of this study, i.e. the typology suggested, the indexed risk acceptability influential factors, as well as their impact in OHS.

2 METHODS

2.1 Literature Review

The study was conducted through an exhaustive review of the literature written about risk acceptability principles and factors. This literature review was carried out between 2013 and 2015, and was not limited to any specific sector. The main keywords used to identify the relevant publications were: *risk; management; assessment; acceptability; acceptable; tolerance; tolerable; principle; criteria; parameter; factor*.

In total, more than 250 publications were found with those keywords. A first analysis, based on the scientific value of the publication regarding the subject of the study, allowed to retain 120 publications, including 87 scientific articles, 18 reports from different organizations, 8 books, 4 standards, and 3 theses. These publications were then classified according to different categories of subjects addressed, presented in Table 1.

Table 1: The different categories of the consulted documents

Categories	Number of documents	Subjects
General presentation of the notion of risk and the concepts of risk acceptability	25	Definition of the terms risk and risk acceptability. Fundamental principles of the acceptable or tolerable risk. Risk acceptability approaches.
Risk acceptability influential factors	43	Importance of the factors, definitions of the factors, specific criteria.
Risk acceptability influential factors in specific fields	52	OHS, health care, transportation, construction, processes, leisure. Criteria, variables, and used thresholds.

2.2 Analysis

2.2.1 Identification of the Risk Acceptability Influential Factors in OHS

All the selected scientific articles, reports, books, standards and theses were analyzed in order to identify the cited factors which, according to the authors of these publications, potentially impact risk acceptability. The research was focused on the notions that support risk acceptability in different fields. As the analysis went along, a database containing the potential factors was built. Some factors were found in many publications, while others were suggested in only one source.

For each factor indexed, the literature was then explored in order to support the potential influence of this factor in OHS.

2.2.2 Development of a Typology and Classification of the Influential Factors

During the literature review, it was noted that some influential factors identified could be considered as subsets of other factors. The factors were hence organized according to a logical structure, allowing to relate the different factors between them. Then, this structure led to the elaboration of a risk acceptability factor typology. Section 3 presents this proposed typology. Section 4 shows the classification of these factors, as well as their description.

3 PROPOSITION OF A RISK ACCEPTABILITY INFLUENTIAL FACTOR TYPOLOGY

The suggested risk acceptability influential factor typology is presented in the following sections. Initially, the factors identified in the literature were considered as risk acceptability "criteria." Since some of those criteria showed similarities, it was possible to gather them into categories called "parameters." Then, it was noted that for certain criteria, the literature provided specifications regarding the way they could be quantified and qualified. These sub-criteria were identified as risk acceptability "variables." Finally, for some of these variables, the literature identifies some "threshold" values that explicitly defined the quantitative limits of risk acceptability or risk tolerability in diverse fields. Figure 2 illustrates by an example the classification model suggested. The following sections define the elements of the typology.

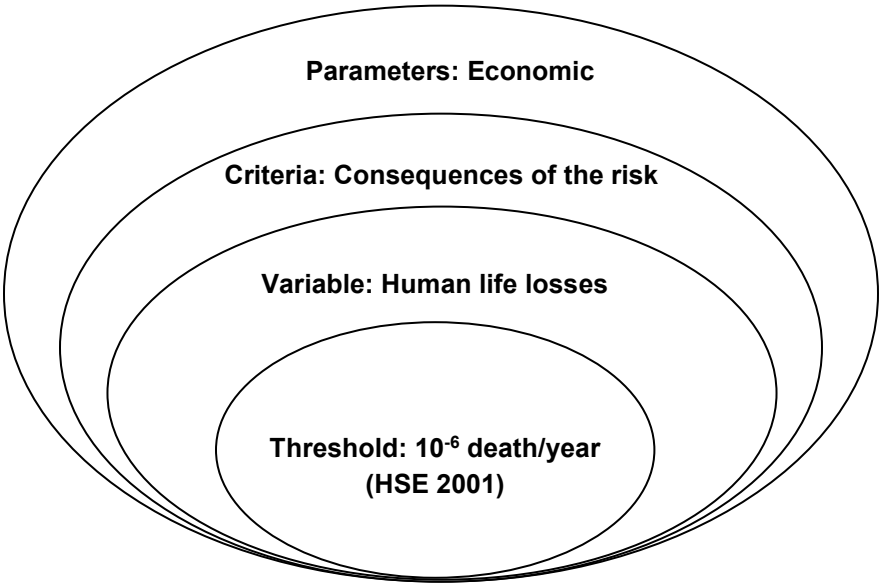

Figure 2: Example of the classification of the risk acceptability factors

3.1 Definition of the Typology

3.1.1 The Parameters

The parameters constitute a set of risk acceptability criteria and variables grouped according to their common characteristics. Some parameters are rather qualitative, while others can also have quantitative criteria (Rodrigues et al. 2011). The classification allowed to distinguish 8 parameters, presented in section 5. The example in Figure 2 illustrates the "economic" parameters with some related influential factors.

3.1.2 The Criteria

The criteria are basic elements of the suggested classification. They define the notions used to determine if a risk is acceptable, tolerable, or unacceptable. The example in Figure 2 shows the criteria "consequences of the risk," one of the criteria of the economic parameters that have the most impact. These consequences can be of human, environmental or technical nature, but they all have economic impacts.

3.1.3 The Variables and the Thresholds

A variable is a sub-criteria of the notion of risk acceptability. They specify the criterion and provide a particular orientation. In the suggested classification, some criteria can have many variables, while others do not have any. Figure 2 shows, for instance, the variable "human life losses," which specify the criteria "consequences of the risk."

For some criteria and their subsequent variables, the literature proposes pre-determinate limit values (thresholds) for a given sector, beyond which the risk is considered unacceptable. For example, for the variable "human life losses," a threshold of 10^{-6} death/year, or one death per one million workers per year, is suggested by the HSE (2001) as the limit for the risk tolerability in the field of OHS.

4 CLASSIFICATION OF THE RISK ACCEPTABILITY INFLUENTIAL FACTORS IN OHS

The classification obtained is presented in Table 2. This classification includes 8 parameters regrouping 19 criteria and 14 variables. Each parameter, as well as the related criteria, variables and thresholds, and their influence in OHS, are described in the following sections.

Table 2: Classification of the risk acceptability factors in OHS

Parameters	Criteria	Variables	Evidence in the literature
Economic	Incurred benefits	• Financial benefits • Temporal benefits	(Wenping & Xia, 2012) (Nordlöf et al., 2015)
	Econo-geographical situation		(Huang et al., 2013); Elenge et al., 2012); (Tomei, et al., 2012)
	Consequences of the risk	• Financial impacts • Human life losses • Severity of the injuries and diseases • Impacts on life expectancy • Environmental impacts	(Gosselin, 2004) (EASHW, 2010), (Waehrer et al., 2007) (Abrahamsen & Aven 2008) (Jongejan, 2008) (Latil, 2015) (French et al., 2005)
Personal	Demographic	• Age of the individuals • Gender of the individuals	(Paap, 2006) (Veevers & Gee, 1986) (Sjoberg & Torell 1993) (Vézina et al. 2011)
	Socioeconomic	• Education level • Level of income • Occupation	(Lu, 2012) (Huang et al., 2013) (Mucenski et al., 2013) (Moseman, 2012)
	Knowledge of the risk		(Aven & Steen, 2010) (Bradley et al., 2009) (Meksawi et al., 2012)
Cultural	Beliefs		(Boudon, 1999) (Patrick, 2005)
	Religious		(Kouabenan, 2008)
Political	Perception and trust that the people have regarding the capacity of institutions to manage risks		(Huang et al., 2013) (Vanem, 2012)
Social	Potential severity	• Reversibility of the consequences • Scale of the potential damages of an event	(Henselwood & Phillips 2009) (Ditlevsen, 2003)
	Influence of the media		(Coleman, 1993) (Hergon et al., 2004) (Gibson & Pattisson, 2014)
Ethical	Personal values		(Guldenmund, 2007) (Galizzi & Tempesti 2015)
	Ethics		(Engineers Canada, 2012) (Vanem, 2012)
Psychological	Perception of the risk		(Douglas, 1986) (Renn, 2004)
	Voluntary risk taking		(Delignières, 1993) (Pardo, 2002) (Banet, 2010)
	Emotions		(Hergon et al., 2004) (Cadet, 2003)
Characteristics of the risk	Comparison of the risk with other situations		(Moseman, 2012) (EN 50126 : 1999) (ISO, 2010)
	Collective or individual risk		(Ball & Boehmer-Christiansen, 2007) (Schmidt, 2007) (Hartford, 2009)
	Speed of onset of the damage		(Maeda et al., 2003)

4.1 The Economic Parameters

The economic parameters group the criteria and variables to which can be assigned a monetary value, and that influence the acceptability or tolerability of a risk. These criteria and variables can be expressed in financial terms, but also in terms of time and consequences. They are described in the following sections.

4.1.1 The Incurred Benefits

In light of the ALARP approach (HSE, 2001), the incurred benefits resulting from taking a risk represent an important criterion in the risk acceptability process. In fact, according to this approach, the risks can be tolerated if the required costs related to the risk reduction measures are excessive and disproportionate in comparison to the benefits expected from the implementation of these measures. Consequently, the decision not to add risk reduction measures and to tolerate the risk shows benefits. These advantages can be of different natures and represent all the benefits that can be derived by deciding to accept to take a risk. In the field of occupational health and safety, two variables can be distinguished from this criterion, the *financial benefits* and the *temporal benefits*.

The potential *financial benefits* related to taking a risk are omnipresent. Because of these profits, some enterprises neglect safety rules, norms or best practices. Therefore, some risks are accepted or tolerated in order to reduce the costs. Although regulations in many countries allow to partially control these kinds of situations, the workarounds are numerous. In the same angle, the *temporal benefits* are also an important decision-making variable in most of the contexts, and safety is sometimes sacrificed on the altar of time (Wenping & Xia, 2012). The optimization of the time required to execute a task or the time needed to complete a project makes it an important criterion in risk acceptability. Under the effect of short timelines and the pressure of the organization, the employees may end up voluntary or involuntary neglecting the best practices with respect to safety (Nordlöf et al., 2015). This type of situation occurs with machine safety, where in many enterprises, the safety features may have been removed or bypassed in order to speed up the tasks (Backström et al., 2000).

4.1.2 The Econo-geographical Situation

The econo-geographical situation is the criterion that links the economic activities to the geographical environment in which these activities are conducted. In a case study of the province of Jiangsu in China, where the chemical industry is the main economic activity, Huang et al. (2013)

have demonstrated that overall, the population was more tolerant to the risks of the chemical industry, the economic lungs of the region. There are many examples where, in regions with high unemployment rates, the inhabitants tolerate more certain risks and work in unsafe conditions in order to support themselves and their families, and sometimes to the detriment of their health (Elenge et al., 2013).

Regarding the econo-geographical situation, the literature refers to certain variables that influence the risk acceptability process. The *type of work contract* can have impacts on the acceptability of professional risks. In many fields, the research shows that temporary workers are more inclined to accept or tolerate a risk than their permanent colleagues. In the construction and agribusiness process (fishery and agriculture) fields, for example, fatal work-related accidents are higher for temporary workers (Villanueva & Garcia, 2011). Likewise, Tomei et al. (2012) and Elenge et al. (2013) demonstrated that the *precariousness of employment* put a certain mental pressure on the workers that can generate work-related accidents and diseases. The precariousness of employment, with its psychological impacts on the workers, can lead to a greater tolerance of the risks. The seasonal workers and those who lives day by day are more affected in this case.

4.1.3 The Consequences of the Risk

The consequences of the risks include many variables that influence risk accessibility depending on its potential impacts: *financial impacts, human life losses, severity of the injuries or diseases* and *impact on life expectancy.*

The variable *financial impacts* directly translates the influence of the monetary value of the material losses, waste of time, deaths and health care required following an event on risk acceptability. In the occupational health and safety field, the financial impact includes the direct and indirect costs of work-related accidents and diseases (EASHW, 2010), (Gosselin, 2004). These costs are relatively high and generally encourage the implementation of preventive measures and the respect of the safety rules. For example, the total costs resulting from accidents in the construction sector in the United States were estimated at 11.5 billion dollars, or almost 15% of the total costs for all the private industry in the United States (Waehrer et al., 2007). In most countries, the companies need to pay premiums to governmental organizations that manage the compensation of workers injured or inflicted by a disease while on duty. The European Agency for Safety and Health at Work (EASHW, 2010) showed that in many cases, there is a correlation between the number of work-related accidents and the premium paid by the organizations. Reducing the risk

of work-related accidents and diseases, as well as their financial impacts, is hence beneficial for the enterprises.

Many acceptability thresholds are associated with the variable *human life losses* by different organizations. For the HSE (2001), a value below 10^{-6} (one death per one million people) per year is considered insignificant, and a value over 10^{-4} is considered tolerable. For the *American Institute of Chemical Engineers*, the threshold for an acceptable risk is 10^{-7}/year when no actions are suggested, and it is considered unacceptable for a value of 10^{-5}/year or over (Moseman, 2012). The threshold can also be expressed in FAR, the Expected Number of Fatalities per 100 million exposed hours (Abrahamsen and Aven 2008). According to Aven & Vinnem (2005), the FAR should be of less than 10 fatalities per 100 million exposed hours for the risk to be considered acceptable. Some thresholds are also expressed based on the LIRA concept (Localized individual risk per annum), which is the probability that an average unprotected person, permanently present at a specified location, is killed during one year due to a hazardous event at an installation (Jongejan, 2008). In Great Britain, the LIRA is also related to the hazardous dose, with a LIRA acceptability threshold of 10^{-5}/year (Johansen, 2010).

The variable *severity of the injuries and diseases* associated with the consequences of a risk is largely used in OHS. The higher the severity of the impacts on people's health and physical integrity is, the less the risk is likely to be tolerated. Indeed, the majority of risk estimation tools, including those used in OHS, utilize the severity of the potential damages as the first parameter in order to establish the level of risk of a given situation (Paques et al., 2007). Furthermore, most of the preventive and compensation organizations use indicators that reflect this variable, in particular in terms of the number of days lost because of an indemnified accident or disease (Duguay et al., 2012). The thresholds of those indicators, even though they do not provide a clear limit of risk acceptability, allow to compare the potential severity of the risk in different industries.

The *impact on life expectancy* is a variable both economic and social. Life expectancy is a measure of the health status of a given population, and can be defined as the average number of years that a person can live. A population of workers exposed to arduous tasks can see its life expectancy reduced by 9 years (Latil, 2015), which can lead to a loss in expertise. It is the case of the workers exposed to asbestos, where the important number of deaths brought about many countries to prohibit or limit the use of this material (CCOHS, 2015).

4.2 The Personal Parameters

The personal parameters gather the criteria and variables linked to the distinctive characteristics of the individuals or populations.

4.2.1 The Demographic Criterion

The demographic criterion includes two variables: the *age* and the *gender* of the individuals. In respect with the variable *gender*, different studies suggest that men are generally more inclined to take risks than women (Paap, 2006; Veevers & Gee, 1986; Sjoberg & Torell, 1993). This tendency seems confirmed by the relative number of work-related injuries and diseases that affect men versus women. For instance, the Quebec Occupational Health and Safety Commission, in Canada, reveals that in proportion, men are more often victims of accidental work-related injuries and diseases than women. Approximately 4.3% of them, in comparison with 2.2% for women, have injured themselves at work severely enough to limit their activities at least once (CSST, 2011).

As for the variable *age*, the results of the study of Huang et al. (2013) suggest that elderly individuals are more hesitant to accept risks than younger people. The works of Vézina et al. (2011) relate the over-representation of the 15 to 24-year-olds among the victims of work-related accidents in the province of Quebec, in Canada.

4.2.2 The Socioeconomic Criterion

Three variables come out from this criterion, namely the individual's *education level, level of income* and *occupation*. Many authors have shown the impact of these variables on the risk acceptability or tolerability process (Huang et al., 2013) (Mučenski et al., 2013) (Lu, 2012). The study of Huang et al. (2013) suggests, among other things, that housekeepers and farmers (generally less educated and with a lower income) considered chemical risks unacceptable, while individuals with average and higher than average incomes are more inclined to accept these risks. In the context of this study, this could be explained, among others, by the fact that the salary of these individuals reflects this risk. Moseman (2012) alleges that a worker usually accepts higher levels of risk when it implies a better salary. The *level of income* variable might show similarities with the *financial benefits* variable from the Economic parameters. However, the *level of income* affects the risk acceptability on an individual, or personal, level, while the *financial benefits* are more associated with the organization's perspective.

4.2.3 Knowledge of the Risk

The level of expertise of an individual influences his assessment of a given situation and issue. Consequently, the knowledge of people regarding a risk impacts their level of acceptability or tolerability. Abrahamsen et al. (2013) claim that the implementation of an expert committee is essential within the ALARP approach. The knowledge of a risk involves self-awareness or social awareness about the existence of the risk, its consequences, and its probabilities. A risk can be accepted or tolerated by lack of knowledge, and can also be declined for the same reasons (Aven & Steen, 2010).

It is obvious that a better knowledge of a given risk allows people to better define their acceptability level regarding this risk. This phenomenon can be observed in occupational health and safety in the context of the risks of Work Related Musculoskeletal Disorders (Meksawi et al., 2012). Indeed, the studies show that the workers that are better trained and better informed on the existence of those risks in their functions are more proactive in the identification of dangerous situations and more engaged with their employer in finding solutions (Cezar-Vaz et al., 2015) (Bradley et al., 2009).

4.3 The Cultural Parameters

The cultural parameters group the mystic-religious criteria linked to the building of collective imaginary. By opposition to a probabilistic interpretation of a risk, the cultural parameters are based on a diversity of cultural and religious beliefs (Gravel & Zayed, 2014).

4.3.1 Beliefs

Beliefs represent a subjective aspect, yet important in the risk acceptability process. It is an individual and sociocultural phenomenon in the extent where it depends on both the individual involved and the social and cultural considerations within the group to which he or she belongs. Boudon (1999) suggests that "*individuals are able to justify their beliefs by supporting them by convincing arguments, even if they are not necessarily fair.*" These arguments are often based on superstitions, religion, luck, and the belief in destiny.

The results of Patrick (2005) regarding some aspects of beliefs with respect to risks are surprising. According to this study, 46% of the people think they have luck and that consequently, they are willing to accept or tolerate a risk simply because they are convinced that because they are lucky, nothing will happen to them. This study also found that 15.6% of the individuals think that

"everything is written" and that they have no control over their destiny, and 20.6% think they have luck and can master their destiny. These beliefs can even lead to deliberately take a risk. These behaviors linked to individual and collective beliefs are also observed in the field of OHS (Kouabenan, 2008) (Nordlöf et al. 2015).

4.3.2 The Religious Criterion

This criterion takes his source in different books and spiritual movements. Religion goes hand in hand with beliefs, values, and moral orientations. A believing and practicing person is part of a community, a group, with its own codes. His or her beliefs can require certain practices and behaviors, with a variable level of flexibility. In health and safety, certain religious beliefs that are at the basis of defensive explanations have a certain influence on the attitude with respect to safety, which directly impacts the level of acceptability of risks. According to Kouabenan (2008), these beliefs determine the individual perception of risks and the decision of respecting or not the protection measures. They can also lead to conflicts between the persons involved regarding the causes of the accidents and the preventive measure to be taken.

4.4 The Political Parameters

The political context surely influences life in society, including what concerns the individual, collective or societal risks. When a population is reassured by the means used by an institution concerning risk prevention, communication and management, the latter is more inclined to accept or tolerate certain risks. People's perception and trust towards the capacity of institutions to manage risks hence represent a political criterion within the risk acceptability process (Huang et al., 2013) (Vanem, 2012). In OHS, this influential factor of risk acceptability or tolerability can apply to workers and their level of trust towards governmental institutions and trade unions, and within the company for which they work.

4.5 The Social Parameters

The social parameters reflect the perceived scale of the risk in the society. Two criteria derive from this, namely the potential severity of a risk and the influence of the media.

4.5.1 Potential Severity

In public opinion, the potential severity of a risk is a strong criterion in risk acceptability. On the basis of the variable *reversibility of the consequences*, the risk would be easier to accept when the damages are reversible (Henselwood & Phillips, 2009). Moreover, according to the variable

importance of the potential damages of an event, a risk can be seen as intolerable when a unique event can lead to important damages, with no regard to the probability of occurrence of this event. Furthermore, the risk acceptability criteria expressed for rare events, but with high potential damages, are more severe than in the case of a risk involving the same cumulated number of potential victims, but distributed over multiple accidents (Ditlevsen, 2003). Situations with high potential severity seem to generate risk aversion in the population. Consequently, on a social point of view, risk acceptability seems more influenced by the potential severity of the risk than by its probability to occur. This is translated, for instance, in a greater awareness of the workers regarding unlikely situations that can lead to deaths (for example, an explosion) in comparison to the risks linked to less severe injuries and diseases, but much more frequent, as for example burns or lacerations.

4.5.2 The Influence of the Media

Media often play an important role in the processes of comprehension, social perception and awareness of certain risks (Coleman, 1993). In doing so, they directly interact with the acceptability or the tolerability of a risk. The communication of risks is a process through which the risk is identified and shared, with the purpose of informing about its inherent threat (De Sa et al., 2009). With the information that they provide, media contribute to the *knowledge of the risk* (ref. 4.2.3). However, media can communicate the risk in a variety of ways, which can sometimes direct the public opinion. They can hence become amplifiers of the risk (Hergon et al., 2004). Moreover, through their media coverage, an important constant flow of information on a risk or an event can increase the attention or the concerns of the public or the workers, and then limit its acceptability. The international response to the article published in *The Guardian* edition of December 23rd, 2014 about deaths among migrant workers building stadiums in Qatar for the 2022 FIFA World Cup is an unequivocal example of the media acting as a risk acceptability influential factor in OHS (Gibson & Pattisson, 2014).

4.6 Ethical parameters

Ethical parameters take into account personal values and rules of professional conduct.

4.6.1 Personal Values

Personal values are proper to each individual. They are preferences and fundamental desires that animate each person. They represent deep motives that support the personal ethics of each individual, and consequently orientate their decisions and their actions. Facing a risk, some

people can be inclined to accept, tolerate or refuse a risk based on their own values that define their personal attitude towards safety. The literature is actually well expanded on the notion of the attitude towards safety in OHS (Guldenmund, 2007). In every enterprise, it is known which workers are naturally more inclined to take risks. The works of Galizzi and Tempesti (2015) have actually shown the extent of the workers' tolerance levels towards risks.

4.6.2 Ethics

In a given job, ethics, or professional ethics, states the codes of good practices, the moral and the sense of duty of the profession. For the firefighter, for instance, ethics intervene in a situation involving a relatively high level of risk in order to save lives. The inherent risks of this occupation are hence tolerated by these workers. In opposition, the engineers' professional ethics oblige them to apply the utmost rigor in their risk assessment, in particular with respect to the workers' safety, and to take into account the results of this assessment when making decisions (Engineers Canada, 2012). To a certain extent, ethics aim at placing moral and professional duties before the risk and its potential consequences within the risk acceptability criteria (Vanem, 2012).

4.7 The Psychological Parameters

It is undeniable that risk acceptability or risk tolerability is influenced by many psychological aspects (Douglas, 1986). These parameters include 3 criteria of risk acceptability that are linked to the perception of the risk, to taking the risk, and to the emotions when facing the risk.

4.7.1 Risk Perception

Risk perception applies to the mental processes through which someone receives, assesses, addresses and takes into account the information in its environment (Renn, 2004). The studies conducted on this topic show that the perception of a risk is a product of the human mind (Hergon et al., 2004). For a repeated danger, risk perception reflects the level of risk to which a population has previously been exposed (Njome et al., 2010). A risk situation can also be perceived differently if it has been experienced recently or if an accident has occurred in recent times. Renn (2004) lists different models of risk perception: the risk can be considered a fatal threat, a fruit of faith, a challenged aiming at testing one's strength, a game of luck, or an alert signal preceding the danger. Consequently, the way risks are perceived leads to the acceptability or the refusal of a risk, while ignoring its objective analysis.

4.7.2 Voluntary Risk Taking

Taking a risk is the action of putting oneself in a hazardous situation. Voluntarily taking a risk consists in taking and assuming the risk by free decision (Pardo, 2002). By opposition, in the case of involuntary risk taking, individuals are encouraged or forced to experience a hazardous situation. The risk is more or less imposed to them. It seems that people accept more easily risks that are taken voluntarily than those taken involuntarily (Delignières, 1993). It is not rare to see, for example, some workers refusing to lift heavy loads in their task description, but to do it voluntarily in their personal activities. Voluntary risk taking also involves the perception of a better control over the risk by the risk taker.

However, the concept of voluntary risk taking remains quite ambiguous; it is hard to establish an unequivocal way regarding the voluntary risk taking for an individual (Banet, 2010). It is possible, for instance, to see the action of voluntarily taking a risk as a state of mind, a function or a task that cannot be refused because of an engagement or a promise made. In this case, taking a risk comes from the function, and the voluntary nature of the decision is not easy to demonstrate.

4.7.3 Emotions

An emotion can be defined as a psycho-physiological reaction of an individual's the state of mind, provoked when confronting a situation, and the interpretation of this confrontation (Hergon et al., 2004). In any life situation, a confrontation arouses emotions that, in the case of a hazardous situation, can lead to accepting or refusing a risk without any rational reasons. The spontaneous decision to enter in turbulent waters in order to rescue someone in distress is a good example. In many circumstances, emotions are an integral part of the risk acceptability process (Vanem, 2012). Regarding OHS, emotions facing risks can be manifested in the form of stress, and many studies have shown the link between taking a risk and the stress experienced by workers (Grill et al., 2015; Elfering et al. 2012; Cadet, 2003).

4.8 The Parameters Defining the Characteristics of the Risk

The parameters that define the characteristics of the risk gather three criteria of risk acceptability that are connected to the very attributes of the risk: its comparison with other risks, its collective or individual nature, and the speed of onset of the potential damage.

4.8.1 Comparison of the risk with other situations

Comparing the risk to other situations is a risk acceptability criterion that can be objective or subjective depending on the circumstances. The GAMAB approach (EN 50126, 1999), for example, is based on the comparison of the characteristics of the risk to a pre-existing situation. This can be done by experts or by knowledgable individuals who have the relevant expertise in that matter. This objective comparison allows to establish the acceptability thresholds by comparing the characteristics of the current risk and its history to other social risk in general (Moseman, 2012). More subjectively, workers facing a risk can also compare it more or less consciously to a previous experience (which might be recent or not) in order decide to accept, tolerate or decline the risk (Delignières, 1993). Incidentally, in its statements of principles regarding the machine-related risks, the Standard ISO 12100: 2010 specifies that the risks associated with one machinery can be compared with those of similar machinery in order to determine if risk reduction is required.

4.8.2 The Collective or Individual Risk

The collective risk (or societal risk) relates to the hazards that can affect a group or a population, with impacts on the organizations and institutions responsible to ensure people's safety (Vanem, 2012). The consequences of these risks can generate political and social responses, like amending laws, rules, or standards (Ball & Boehmer-Christiansen 2007). As for the individual risk, it potentially affects an individual or a few people. It influences a person's perception of a hazard depending on the way it can affect this person, his or her near relations, and his or her valuable goods (HSE, 2001). Given the potential impact of these two types of risks, their level of acceptability or tolerability may vary. For instance, the concerns with respect to safety are generally greater in the chemical process industry, where certain events can affect multiple workers or even a whole population, than in the traditional manufacturing industry. It goes without saying that the level of acceptability of an individual risk largely depends on the tolerance of the person taking the risk. As for the collective risk, it is more influenced by the societal context in which evolves the organization or the institution, each organization being responsible to establish its own limits of acceptability (Schmidt, 2007). The threshold of acceptability of the individual risk varies between 10^{-6} to 10^{-4} deaths/year in most domains of human activity (Hartford, 2009). In the oil industry, the threshold of the risk acceptability is below 10 deaths by 100 million working hours (Abrahamsen & Aven, 2008).

4.8.3 The Speed of Onset of the Damage

The speed of onset of the damage is a criterion not well documented. However, it seems that when the speed of onset of the damage is potentially quick, the risk is less easily accepted than if the speed is slow. It is notably the case for the risks related to certain professional diseases, which can have very serious long-term impacts on workers, but for which the preventive measures are often less well implemented than for the risks emanating from work-related accidents, like falls from height or machine-related accidents (Maeda et al., 2003).

5 DISCUSSION AND CONCLUSION

This study has identified 8 parameters, regrouping 19 criteria and 14 variables (Table 2) that influence risk acceptability or risk tolerability in OSH. Even if an effort was made to clearly distinguish these factors, some overlap between the different criteria and variables is unavoidable. These factors can also influence each other to some extent. For example, the *beliefs* and the *personal values* criteria can be founded on the same basis personality traits. However, these parameters surely represent a significant proportion of the factors that impact the risk acceptability process in OHS.

These results suggest that the decision to accept a risk in OHS is rather subjective. Indeed, in the risk management process, the majority of these influential factors identified are qualitative and draw on the personal perception, values and characteristics of the individuals involved or in charge (workers, company managers, health and safety officers, production managers, etc.). This might be the most important finding of this study. A better awareness of these factors could encourage a better management of health and safety by acting on the behavioral aspect in the decision-making process with respect to taking risks in work environments. In effect, these results could influence the policies and the communication strategy of OHS organizations at all levels.

Even if more research is needed in order to establish the relative importance of all these factors, the results suggest that the economic and personal parameters are the most important in OHS, if one considers the different variables associated with them. With respect to economic parameters, the criteria *consequences of the risk* is composed of many variables that can be quantitative. The thresholds associated with the variables *human life losses* and *severity of the* injuries and diseases are actually largely considered as the indicators of the OHS objectives of states and organizations. Eurostat (2014) reveals that for 2009 in Europe, 5 deaths/year per 100 000 workers in Cyprus were observed, while Luxembourg, Denmark, Finland, the Netherlands, Germany,

Sweden, and Great Britain showed values between 0.5 and 1.5 deaths/year per 100 000 workers. As for Canada, Human Resources and Skills Development Canada establishes the average number of fatalities to 6.3 deaths/year per 100 000 Canadian workers between 1996 and 2008 (Gilks & Logan, 2010).

As for the personal parameters, it is interesting to note that some of the criteria and variables that it comprises tend to indicate that more vulnerable people can be more inclined to accept or tolerate risks. This observation reinforces the necessity for organizations responsible to implement OHS to better legislate and ensure a better surveillance in the working environments, in addition to encourage a better dissemination of knowledge about OHS in the society as a whole.

On their side, the cultural, political and social parameters clearly show the impact of the socio-cultural context in which the concerned individuals evolve on the acceptability of risks in OHS. Regarding the ethical and psychological parameters, they suggest that an important part of the decision-making process regarding risk when facing a hazardous situation rests upon individual characteristics. Policies with respect to OHS management need to take into account these considerations and direct their approach, rules and dissemination of information consequently.

However, these results should be completed by a field study that would allow to understand the influential criteria and variable implementation process in real risk acceptability decision-making process contexts in occupational health and safety. More specifically, it seems essential to better comprehend how are those criteria and variables explicitly or implicitly engaged in the decision-making process.

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