Integrating human attitude in risk assessment process

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Abstract

The notion of risk is a pervasive one nowadays, due probably to the fact that, though the humanity is living in an advanced technology era, it is not fully protected from catastrophic events, be them natural or resulting from human activities; even this advanced technology is creating new treats for the humanity. Thus, to avoid extreme reactions with regards to these risks and in order to be armed to manage efficiently these risks in terms of resources allocation, the notion of risk must be addressed scientifically when taking into account social, cultural, moral, philosophical, psychological attributes of human beings. This paper aimed to establish a framework that permits to analyze a system (physical objects such as an infrastructure, production plant; organizational system; managerial system, etc.) with regards to risk it may face. Two main issues are addressed in the paper: structuring risks identification and impact assessment process and measuring risk taking into account the nature of the system under review and stakeholders or decision makers attitude towards risk for the purpose of resources allocation for instance. To be sound and robust, a structuring approach must rely on some concepts; in this paper, bipolarity, in the sense that facing an adverse event a system will exhibit resistant as well as weak aspects, will be the underlying structuring concept.

Keywords: resilience, vulnerability, risk assessment, human attitude, risk averse, risk taking

1 Introduction

Integration of risk factors in decision making or risk informed decision making is receiving a great attention by researchers and decision makers in many domains such as engineering (designing technical systems that mitt some requirements in terms of safety), finance (setting up norms to monitor finance activities in order to avoid companies collapse), environment (developing sustainable agriculture and natural resources extraction actions), science and medical research (monitoring scientists activity by the society to avoid creating new threats); because national and international opinions are being more and more sensible to risk issues from all human activities as well as natural phenomena (earthquake, hurricane, tsunami, floods, etc.). Risk comes from the incapacity of human beings to correctly predict the outcomes of some events from the environment of the system under consideration or their actions on this system. Indeed, risk and uncertainty are fundamental elements of modern life so they must be managed effectively to protect people from injury and to permit the development of reliable, high-quality and sustainable products. Today an ever-increasing number of professionals and managers in industry, government, and academia are devoting a larger portion of their time and resources to the task of improving their approach and understanding of, risk-based decision making [5, 6]. Indeed, decision making under uncertainty (risk) literally encompasses every facet, dimension, and aspect of our lives. Any decision maker needs to cope with uncertainty in order to rationally act in the sense of risks reduction. To correctly and scientifically address risk management process that is filtering risk factors, selecting and prioritizing appropriate actions, one needs to dispose of risk measure. These decisions or actions can be divided into three categories: *pre-active decisions,* these decisions consist in doing things to prepare

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the system under consideration to face potential adverse events (one knows that such events will occur soon or later). Actions such as transferring risk by contracting insurances, editing anti-seismic construction norms in the case of natural disasters or prudential norms such as those of Bâle II (see for instance [11]) concerning banking activities, preparing population on how to behave in the case of an earthquake, constructing and organizing emergency facilities, etc. are pre-active decisions. Beside of pre-active actions, one may need *reactive decisions* that are real time decisions to be made when the undesirable event does really occurs and *pro-active decisions* that consists in doing things to avoid the occurrence of catastrophe when possible for instance, see for instance [10]. Of course in the case of natural disasters there is no possibility to prevent the occurrence of undesirable events; therefore it is not formerly possible to make pro-active decisions; though actions that tend to prevent the effect of climate change can be considered to be pro-active decisions toward the management of natural disasters. This paper deals with issues of identifying risk factors and measuring risk to guide decisions makers to make sound and efficient decisions. Risk measure depends on decision maker attitude (fear, emotion, culture, experience, etc.) mainly in what concerns extreme events.

2 Risk Identification and Impact Measurement

In this section, a process of identifying risks a system may face, their consequences and the impact on these consequences will be derived.

2.1 Risk Identification

Identification process is a purely analytic activity where the analyst is willing to characterize the risks faced by a system by following some procedures. Risk modeling, assessment, and management as any decision oriented process should begin by defining the object to be studied in terms of risk. In this work we are considering a generic object that we refer to as an entity or a system. In a second step toward risk issue consideration, one should precisely define the border of this system (what is included or considered in the system and what should be considered as outside or environment of the system). Once, this work is done one can consider identifying undesirable events (that are often confounded with risk in an abuse language in literature) that may threaten the system. Given previous distinction as system and its environment, the origin of these events may be internal or external. The process of identifying risks a system may be facing will begin by answering a question of the form $\ll$ what can go wrong ?$\gg$ as proposed by [4] to end up with a set $\mathcal{X}$ of potential undesirable events or risks (in a common statement). This process may go from undesirable events to their impact or consequences on the system, this analysis is referred here as forward analysis and is well suited when undesirable events are well defined such as natural risks (earthquake, tsunami, etc.). One can also go from potential consequences to identify their potential causes, that is on backward analysis basis.

2.1.1 Forward Analysis

When the primary undesirable events (earthquake, floods, hurricane, etc.) are clearly identified so that, in terms of risk identification, one will just answer the questions "what are the consequences?" and "what is the likelihood of the undesirable event"; the response to this question leads to identifying two types of consequences: external consequences and internal consequences. External consequences (tsunami resulting from earthquake for instance) constitute actually new undesirable events. There may exist interactions between these events, forming what we refer to as events cluster, leading to new internal consequences. In the same way there may exist interactions between internal consequences leading to consequences cluster. Internal consequences depend not only on the undesirable events but also on the state of the system that is all attributes of the system that render these consequences more or less severe.

2.1.2 Backward Analysis

Here one goes from potential negative impact on the system, that is from consequences, and then progressively identify external or internal events that may cause these troubles. The answer to the question, *"what can go wrong?"*, will permit to identify all events or sequence of events (or scenarios) that have an (negative) effect on the system. The question, *"what is the likelihood that it would go wrong?"*, is the quantification process to estimate probability of occurrence of former identified risk factors or events. The consequences result from the events as well as the state of the system; the state of the system here consists in all things (cognitive, physical, organizational, architectural, sensitivity, adaptive capacity, etc.) that make it vulnerable or resilient to undesirable events.

2.2 Impact Measurement

The impact of an undesirable event on an entity will depend on the state of this entity; in order to structure the analysis of this state regarding the event, we propose to do it on a bipolar basis that is considering separately things that make this entity resist on one hand and those rendering it weak or sensitive on the other hand.

2.2.1 Resilience and Vulnerability Assessment

The process of identifying consequences, that is the impact on the system if an adverse event does really occurs, needs that the analyst determine the attributes of the system that may make it resilient or vulnerable with regards to the adverse event, that is using a bipolar analysis basis. Given an event X and a consequence C, we refer to these attributes as the state of the system with regards to C given X. Resilience and vulnerability are two notions that are tightly associated to risk and their definitions dependent on the study domain (engineering, economics, management, medical, etc.), but the underlying meaning is almost the same. Indeed, resilience is defined as "the ability of an entity or a system to resist to a major threats or shocks", see [7], whereas vulnerability is related to the "possibility of that consequence to be very sensitive to the considered event". Thus to identify resilience attributes of consequence C denoted by $\mathcal{R}(C/X)$ with regards to event X, one may use questions of the form "what are features of the system that may permit consequence C to recover its nominal level after being impacted by event X ?"; concerning vulnerability attributes denoted by $\mathcal{V}(C/X)$, a similar question may be used, that is "what are features of the system that make consequence C very sensitive to event X ?". The state of system $\mathcal{S}(C/X)$ is therefore the union of $\mathcal{R}(C/X)$ and $\mathcal{V}(C/X)$, that is $\mathcal{S}(C/X) = \mathcal{R}(C/X) \cup \mathcal{V}(C/X)$.

Let us denote by $\rho(a/X) \in [0,1]\ \forall\, a \in \mathcal{R}(C/X)$, the resilience degree of resilient attribute a and $\upsilon(a/X) \in [0,1]\ \forall\ a \in \mathcal{V}(C/X)$ the vulnerability degree of a vulnerable attribute a regarding event X. The overall resilience degree $\rho(C/X)$ and vulnerability degree $\upsilon(C/X)$ for consequence C in front of event X are given by equations (1) and (2)

$$\rho(C/X) = Aggreg_{a\in\mathcal{R}(C/X)} \left\{\rho(a/X)\right\}, \tag{1}$$
$$\upsilon(C/X) = Aggreg_{a\in\mathcal{V}(C/X)} \left\{\upsilon(a/X)\right\}, \tag{2}$$

where *Aggreg* is an aggregation operator. Many approaches, see [2], exist to construct an aggregation operator ranging from simple weighted sum to more sophisticated approach that take into account some interaction between measures to aggregate, see [3]. One such approach known to cope with synergy (when some measures are complementary) between measures, redundancy (the case where some measures are substitutable) and independency between measures is the Choquet integral [1]. Given the synergy of each category of attributes, namely resilience attributes and vulnerability attributes, an appropriate aggregation operator may be a Choquet integral associated to a weighted cardinal fuzzy measure that has an advantage to lead to a straightforward formula for the integral, see [9].

Identified consequences can be compared using these vulnerability and resilience degrees; for instance *robust* consequences are those for which resilience exceeds vulnerability in some sense whereas those for which the resilience is below the vulnerability are the *fragile* consequences; this distinction may guide decision makers in resources allocation phase.

2.2.2 Severity Assessment

As stated in the previous section, the severity of an event for a given consequence will depend on the state of the system regarding that consequence. The state of the system in risk analysis is therefore consequence and event dependent; and results from all attributes of the system that influence the level of that consequence in front of that event. This consideration will help experts when assessing the severity of an event on a consequence; let us, denote by $\sigma(C/X) \in [0,1]$ the severity degree of the impact of event X on consequence C; this measure is naturally a function of the resilience and the vulnerability as given by the following equation (3)

$$\sigma(C/X) = \sigma\left(\upsilon(C/X), \rho(C/X)\right) \tag{3}$$

where the function σ verifies the following hypothetical properties:

- it is an increasing function of $\upsilon(C/X)$ and a decreasing function of $\rho(C/X)$;
- the severity faced by a non resilient system is commensurate to its vulnerability, that is $\sigma\left(\upsilon(C/X), 0\right) \sim \upsilon(C/X)$;
- a non vulnerable system does not face any severity what ever its resilience is, that is $\sigma\left(0, \rho(C/X)\right) = 0$ $\forall\ \rho(C/X)$;
- the maximum severity is obtained for a highly vulnerable and not resilient system, that is $\sigma\left(1, 0\right) = 1$.

A possible such function is given by equation (4)

$$\sigma(C/X) = \frac{\left(\upsilon(C/X)\right)^{a}}{1 + \left(\rho(C/X)\right)^{b}} \tag{4}$$

where a, $b > 0$ are positive real turning parameters.

Given an event X, severity analysis and assessment will follow a hierarchical analysis until consequences for which experts are able to estimate the resilience and the vulnerability are reached. The main goal of this scheme of severity analysis and assessment in terms of risk management decision making (mainly resources allocation) is twofold: risk quantification and events categorization and filtering and optimal allocation of resources when a systems face different undesirable events; and for a given event finding potential management actions and their optimal resources allocation.

3 Risk Quantification

It is widely admitted that risk is measured through two components: the likelihood of the undesirable event X, measured by its probability of occurrence $\Pr\{X\}$ and the level of its negative impact, measured by its severity on consequences, $\sigma(C/X)$ for consequence C. These two measures can be used for filtering purpose in the case of multi-risks (multiple undesirable events) by categorizing these events for a given consequence or categorizing consequences for a given event. The former process is the most studied one in the literature where events are often represented in the plan $\left(\Pr\{X\}, \sigma(C/X)\right)$; four categories of events known as extreme events can be deduced as shown by the following Figure 1.

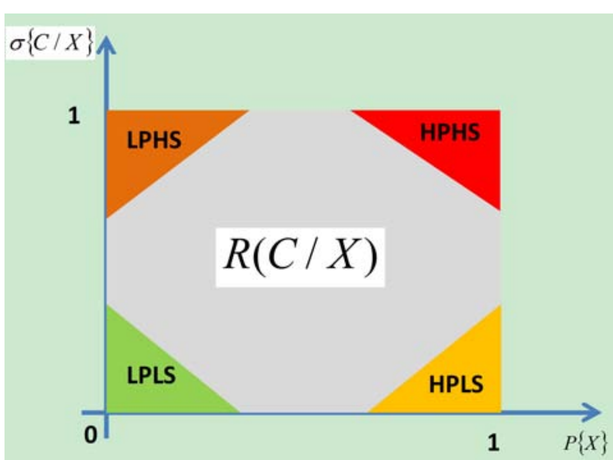

Figure 1: Events categorization in the plan (probability, severity)

The signification of these categories is explained in the following items.

- Low probability – low severity events (**LPLS** events): for these events, probability of occurrence and severity tend together to zero so that one can consider their risk to be negligible; they constitute a category of extreme events.

- High probability – high severity events (**HPHS** events): these factors are those to avoid because their risk is near maximal as they are frequent with high consequences; this is another category of extreme events.

- Low probability – high severity events (**LPHS** events): these are extreme events known in the literature as rare events with high consequences. Perceived risk of these factors will depend on decision maker(s) attitude towards risk. For these events decision maker(s) actions will consist mainly in risk mitigation (reducing the severity).

- High probability – low severity events (**HPLS** events): these are also extreme events for which the perceived risk is dependent on the decision maker(s) behavior; and for which risk prevention (reducing event likelihood) are recommended when possible.

For events that do not belong to one of these four categories, filtering and/or management actions will be based on the measure of the risk denoted $R(C/X)$. Classically, see [6], this measure is given by the following equation (5)

$$R(C/X) = \Pr\{X\}\,\sigma(C/X); \tag{5}$$

from now, in order to simply the notation we will set $\Pr\{X\} = x$, $\sigma(C/X) = y$ and $R(C/X) = R(x, y)$. But this measure does have some drawbacks in practice:

- it is symmetric meaning that extreme events LPHS and HPLS will not be differentiated whereas in terms of resources allocation for risk management decision maker, depending on his personality, may not consider them as equivalent;

- if one of the parameters x or y is fixed, risk behave linearly with regards to the another one (see Figure 2); whereas some decision makers that like taking risk may consider that the real risk is below this line; when risk averse decision maker may consider the risk to be above the line; in fact classical measure corresponds to risk neutral attitude.

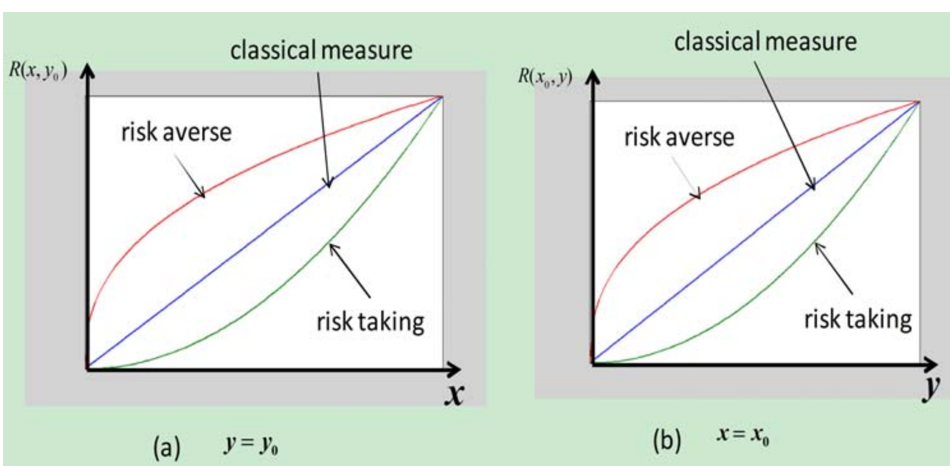

Figure 2: Risk measure behaviour for risk neutral, risk taking and risk averse attitudes

To overcome these drawbacks, we propose in the following section a measure that take into account previous raised issues and that can be reduced to the classical measure for some particular parameters of its law.

4 Proposed Measure

We propose to defined the risk measure by a generalized function $R(x, y)$ as shown by equation (6)

$$R : [0, 1] \times [0, 1] \to [0, 1] \, , (x, y) \to R(x, y) \tag{6}$$

with following properties:

- monotonicity: $x \leq x_0$ (respect. $y \leq y_0$) $\Rightarrow R(x, y) \leq R(x_0, y) \ \forall \ y$ (respect. $R(x, y) \leq R(x, y_0) \ \forall \ x$);
- there is no risk for improbable events nor not severe ones, that is the function $R(x, y)$ verify: $R(0, y) = R(x, 0) = 0, \ \forall \ x, \ y$;
- the maximum risk of 1 is attained for a quasi certain event with maximal severity on the considered consequence, that is $R(1, 1) = 1$;
- $R(x, 1) = f(x)$ and $R(1, y) = g(y)$ where f and g are non decreasing functions verifying $f(0) = g(0) = 0$ and $f(1) = g(1) = 1$;
- continuity: $R(x, y)$ is continuous in its two variables.

It is well known from psychologists that, in general a decision maker exhibits two attitudes: being risk taker for events whose probability of occurrence (respect. severity) is below a given threshold and risk averse for events for which the probability of occurrence (respect. the severity) is above that threshold as shown by Figure 3.

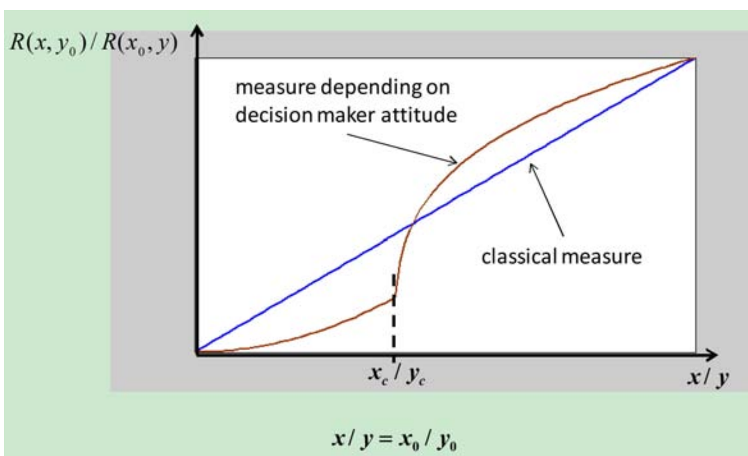

Figure 3: Risk measure behaviour taking into account decision maker attitude toward risk

One such risk measure is given by equation (7)

$$R(x, y) = f(x)g(y). \tag{7}$$

Functions f and g verify following conditions: f (respect. g) is convex for $x \leq x_c$ (respect. $y \leq y_c$) and concave for $x \geq x_c$ (respect. $y \geq y_c$) where x_c and y_c are critical thresholds above which attitude of decision maker switch from risk taking to risk averse. A function f that fulfills above requirements is given by equation (8)

$$f(x) = \begin{cases} Kx^{\alpha_1} \ if \ x \leq x_c \text{ with } \alpha_1 \geq 1 \\ \\ K \left(x - \overline{x}\right)^{\alpha_2} \ if \ x \geq x_c \text{ with } 0 < \alpha_2 \leq 1 \end{cases} \tag{8}$$

where K and $\overline{x}$ are parameters to be determined; as f is a continuous function, we shall have relation of equation (9) for $\overline{x}$

$$Kx_c^{\alpha_1} = K \left(x_c - \overline{x}\right)^{\alpha_2} \Rightarrow \overline{x} = x_c - \left(x_c\right)^{\frac{\alpha_1}{\alpha_2}} \tag{9}$$

and the condition $f(1) = 1$ leads to the value of K given by the following equation (10)

$$f(1) = 1 \Rightarrow K = \frac{1}{\left(1 - x_c + (x_c)^{\frac{\alpha_1}{\alpha_2}}\right)^{\alpha_2}} \tag{10}$$

so that the function f is completely defined by equation (11)

$$f(x) = \begin{cases} \frac{x^{\alpha_1}}{\left(1-x_c+(x_c)^{\frac{\alpha_1}{\alpha_2}}\right)^{\alpha_2}} \; if \; x \leq x_c \text{ with } \alpha_1 \geq 1 \\ \\ \frac{\left(x-x_c+(x_c)^{\frac{\alpha_1}{\alpha_2}}\right)^{\alpha_2}}{\left(1-x_c+(x_c)^{\frac{\alpha_1}{\alpha_2}}\right)^{\alpha_2}} \; if \; x \geq x_c \text{ with } 0 < \alpha_2 \leq 1 \end{cases} . \tag{11}$$

A similar reasoning leads to the function g given by equation (12)

$$g(y) = \begin{cases} \frac{y^{\beta_1}}{\left(1-y_c+(y_c)^{\frac{\beta_1}{\beta_2}}\right)^{\beta_2}} \; if \; y \leq y_c \text{ with } \beta_1 \geq 1 \\ \\ \frac{\left(y-y_c+(y_c)^{\frac{\beta_1}{\beta_2}}\right)^{\beta_2}}{\left(1-y_c+(y_c)^{\frac{\beta_1}{\beta_2}}\right)^{\beta_2}} \; if \; y \geq y_c \text{ with } 0 < \beta_2 \leq 1 \end{cases} . \tag{12}$$

In practice, how critical parameters x_c and y_c must be determined should be correctly addressed; they certainly depend on the psychological attributes of decision makers and may depend on each other that is x_c may depend on y and y_c on x. To derive them questions such as "how likely should be an event and/or at what level of its severity will you buy an insurance to protect the considered system ?" may be helpful. In the same way, derivation of shape parameters α_1, α_2, $\beta_1$and β_2 will depend on each decision maker.

Following items give some comments about the proposed risk measure that can be used for its parameters derivation for instance and show that for a particular combination of shape parameters one recover classical measure highlighting by the way the generalization property of the proposed measure.

- if $x_c = 0$ (respect. $y_c = 0$) then $f(x) = x^{\alpha_2}$ (respect. $g(y) = y^{\beta_2}$) meaning that the corresponding decision maker always has risk averse attitude;
- if $x_c = 1$ (respect. $y_c = 1$) then $f(x) = x^{\alpha_1}$ (respect. $g(y) = y^{\beta_1}$) so that we have always risk taking decision maker;
- if $\alpha_1 = \alpha_2 = \alpha$ (respect. $\beta_1 = \beta_2 = \beta$) then $f(x) = x^{\alpha}$ (respect. $g(y) = y^{\beta}$) and the risk attitude is determined by the common value α (respect. β);
- if $\alpha_1 = \alpha_2 = \beta_1 = \beta_2 = 1$ then $f(x) = x$ and $g(y) = y$ so that we recover the classical risk measure given by equation (5).

The benefit brought by the risk measure presented in this paper over the classical measure can be viewed at management level mainly in what concerns risks filtering and resources allocations processes. Indeed, by eliminating the symmetry in the risk measure, managers will not threat LPHS events in the same way as HPLS events, that is, their actions will depend on their psychological attributes.

5 Conclusion

The issue of deriving a risk measure that takes into account human attitude has been considered in this paper. Building on classical indicators that enter in risk measurement, namely the probability of occurrence of undesirable event and its severity on some consequences, a general decision maker dependent risk measure has been proposed that reduce to classical measure for a particular combination of its law parameters. Furthermore, using a bipolar analysis approach a method is proposed that permits to compute the severity through resilience measure and vulnerability measure. This bipolar structuring approach has a practical importance because it guides decision makers in gathering necessary information (weakness attributes and/or strength attributes of the considered system) that permits to evaluate the severity degree of a given undesirable event on a given consequence. This hierarchical decomposition will be of great interest during risk management process to identify attributes to improve.

References

[1] Grabisch, M., Fuzzy integral in multicriteria decision making, *Fuzzy Sets and Systems*, vol.69, pp.279–298, 1995.

[2] Grabisch, M., The application of fuzzy integrals in multicriteria decision making, *European Journal of Operational Research*, vol.89, pp.445–456, 1996.

[3] Grabisch, M., K-order additive discrete fuzzy measures and their representation, *Fuzzy Sets and Systems*, vol.92, pp.167–189, 1997.

[4] Haimes, Y., Kaplan, S., and J. Lambert, Risk filtering, ranking, and management framework using hierarchical holographic modeling, *Risk Analysis*, vol.22, no.2, pp.383-397, 2002.

[5] HM TREASURY, *The Orange Book: Management of Risk - Principles and Concepts*, Crown, 2004, *https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/220647/orange_book.pdf.*

[6] Magne, L., and D. Vasseur, *Risques Industriels, Complexité, Incertitude et Decision: une approche interdisciplinaire*, Lavoisier, 2006 (in French).

[7] Omer, M., Mostashari, A., and R. Nilchiani, Measuring the resiliency of the manhattan points of entry in the face of severe disruption, *American Journal of Engineering and Applied Sciences*, vol.4, no.1, pp.153–161, 2011.

[8] Singpurwalla, N.D., *Reliability and Risk: A Bayesian Perspective*, John Wiley & Sons, p.396, 2006.

[9] Tchangani, A.P., Bipolar aggregation method for fuzzy nominal classification using weighted cardinal fuzzy measure (WCFM), *Journal of Uncertain Systems*, vol.7, no.2, pp.138–151, 2013.

[10] Tchangani, A.P., A model to support risk management decision-making, *Studies in Informatics and Control*, vol.20, no.3, pp.209–219, 2011.

[11] Thoraval, P.-Y., Le dispositif de Bâle II: rôle et mise en oeuvre du pilier 2, *Revue de la stabilité financière*, vol.9, pp.125–132, 2006 (in French).