International Journal of Innovation and Applied Studies
ISSN 2028-9324 Vol. 16 No. 2 Jun. 2016, pp. 309-313

http://www.ijias.issr-journals.org/

Modeling of risks of severity via the Bayesian networks: case of the risk of error in insurance

Fatima Zahra EL ARIF

Department of Economics and Management,
Research laboratory in Management, Financial systems and Risk management
Hassan II University, Ain Chock Faculty,
Casablanca, Morocco

ABSTRACT: By looking for a formal method for the management, the use of the Bayesian networks came a natural choice. The Bayesian networks offer a formal frame, but also the ease of learning, and the adaptation to the new data or the requests. In the literature there are numerous examples which present the use of the Bayesian networks in the risk management in diverse sectors such as: financial, medical or legal. In this article we chose the domain of the insurance. Indeed, we propose an example of application of the Bayesian networks at the risk of error in an insurance company.

KEYWORDS: Bayesian networks, risk, severity, financial sector, insurance company.

1 INTRODUCTION

The Bayesian networks join the sphere of influence of the networks of neurons, the artificial intelligence, the data mining. They reconcile knowledge, uncertainty and probability. The notion of risk is of the domain of the uncertain, only the perception which we have of this risk or his realization allows to measure it. In a more technical context alone the knowledge allows to perceive the risks. The risk, or probability of a damage, is so going “to navigate” between the uncertain and the determinism.

But we cannot speak about risk without model. Indeed, a model is the representation of a knowledge at the given moment. The perception of the risk is a model of its possible realization. A bayesian network is at the same time a graphic model of qualitative representation of the knowledge - in its construction phase it integrates the knowledge of experts by representing these knowledge and the causal relations of the various variables by graphs (causal graph connecting causes and effects) - as well as a system of calculating conditional probabilities - we call on in a second phase to the statistical analysis to plan the evolution of these variables.

Thomas Bayes, mathematician and Anglican pastor, whose book “Essay Towards solving a problem in the Doctrine of chances” [1] was published posthumously in 1763, defines the concept of conditional probability. It highlights the fact that the probability of an event to come uncertain and depends on the level of available information before the occurrence of the event. This concept is important because it expresses the fact that uncertainty is specific to each according to his level of knowledge and therefore is closer to a belief than to a frequency. According to Bayes' theorem that probability be revised as and when the information is revisable: P (X / i). The concept of belief takes precedence over the notion of objectivity.

Pierre-Simon de Laplace published in 1812 his “Analytical Theory of the Probability” [2] and also countered that “the insurance of the one who knows only the frequencies is lower than that of that who masters the 'laws' of the nature”.

The interest of the Bayesian networks lives in the fact that they take into account the uncertainty in the process of analysis and reasoning, and so give the possibility of acting in an uncertain environment. A Bayesian network allows to analyze, to exploit important quantities of data to obtain useful knowledge for: make decisions, make diagnoses, check a system, feign the behavior of a system, etc.

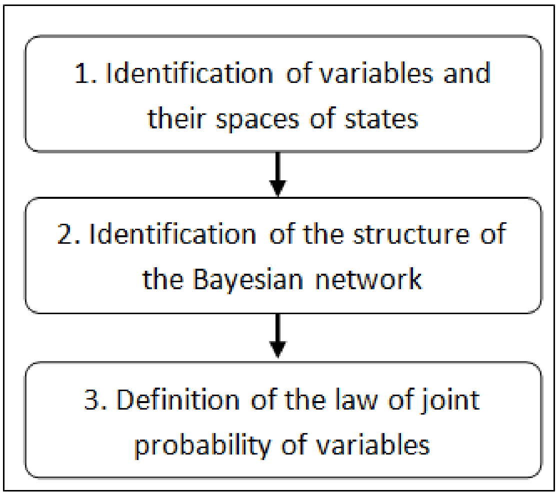

Fig. 1. Stages of construction of a Bayesian network

2 GENERALIZATION OF THIS APPROACH BY THE MODEL XOS[1]

We introduce the basic notion of Vulnerability (methodology ARM) there which is defines by the resource exposed to the risk / danger / the consequence. A mapping is going to cross resources and dangers and of this fact is going to identify the most critical vulnerabilities. A Bayesian network is going to be so declined for every component (exposure, occurence, severity) [3].

The qualitative analysis process is complete, the quantitative analysis can be realized ; the measures of reduction (avoidance, prevention, protection) will be modeled to obtain a cost of the risk equal to the residual risk more the sum of the cost of the measure and the cost of opportunity. This stage of “Transposition of the contract of knowledge” between the risk manager and the modeller around a scenario is decisive.

Once this contract was validated, the model of risk can be used by a simulation of Monte Carlo.

As for the interdependence of the risks, we can aggregate them by an external variable. The insurances can be taken into account to make a simulation of the flows of disasters, verify if the cover is undersized, etc. A simulation of set will give a global vision and a vision by subset, the calculation of the cost of the risk of set taking into account interdependences and insurances.

It is then advisable to ask itself the relevant questions as well as to realize an analysis of sensibility which are going to turn out precious tools of feedback and evaluation to validate a method, modify a system etc.

3 MODELING OF RISK OF SEVERITY VIA BAYESIAN METHOD

The Bayesian approach is to conduct a qualitative risk analysis by experts and turn it into a quantitative analysis.

A Bayesian network is a probabilistic causal graph representing the structure of knowledge in a certain field. It consists of discrete random variables connected by directed arcs, these variables are called nodes [4].

Distribution is attached to each node. Arcs are links that represent causal dependence.

[1] *XOS : exposure, occurrence, severity.*

We studied in particular the method XOS (exposure, occurrence, severity), which is to define and model the three characteristic parameters of risk : the exposure, the occurrence and the severity. These three variables are influenced by variables called Key Risk Indicator (KRI) [3].

We are going to present the methods to estimate the various elements of the Bayesian network.

Assessment of exposure : The exposure is all the elements of the company which are exposed to the risk. She must be defined so that the risk can arise only once in most in the year.

Assessment of occurrence : The item of exposition being selected so that it can be stukch only in most only once, the occurrence will be built by a binomial distribution B (n, p), where n is the number of exhibits and p the probability which we shall have to estimate.

Assessment of severity : It is necessary to take place in the situation where the occurrence of the loss is proven, and to identify the quantifiable variables (KRI) occuring in the calculation of the severity.

The structure of the Bayesian network is defined by the experts through scenarios. Bayesian network parameters can be determined empirically or by experts.

Once the Bayesian network built, it remains to define the algorithm of calculation.

Let $(X_1, X_2, ..., X_n)$ are exposed objects at the studied operational risk.

Let $P_i = P(Exposure = X_i)$ the probability that exposure let be objects X_i.

Let $PS_i = P\ (Occurrence = "yes" \mid Exposure = X_i)$ the probability of the risk occurring given that the exposure is X_i.

These two probabilities are known (they were estimated as seen above).

Let PG_i is $= P\ (Severity \mid Occurrence = "yes"\ and\ Exposure = X_i)$ the distribution of the severity knowing that the risk occurred on $X_i$objects.

The algorithm consists in realizing successively the following steps :

1. Position exposure to X_i, the occurrence to Yes in the Bayesian network and read the distribution of severity $PG_i = P\ (Severity \mid Occurrence = "yes"\ and\ Exposure = X_i)$.
2. Sample the number of losses F_i according to binomial law $B\ (nb(X_i)\ ;\ PS_i)$.
3. For each incident of 1 to F_i, sample the severity according to the PG_idistribution.
4. Sum the severities F_i.

By repeating these 4 steps a large number of time by keeping the sums of the severity every time, we so obtain a distribution of total losses.

4 EXAMPLE OF APPLICATION OF THE BAYESIAN METHOD

We now apply the Bayesian model to the risk of error in the passage of orders, on an insurance company. This risk is treated very simply because our idea is to show how the Bayesian approach applies.

The first step in the Bayesian approach is to create the network using a graph, and define the distributions corresponding to each factor. These parameters can be reviewed in a phase of "back-testing".

An analysis of this risk has allowed us to build the graph [Fig. 5].

Recall that the Bayesian approach proposed for operational risk is to define three objects: the exposure, the occurrence and the severity.

The exposure : the exposure has to correspond to the objects of exposition of the company which can be touched by the risk only once for the period.

We chose the orders. Indeed, an order can be erroneous only once. We do not anticipate increase in the number of orders for year to come and the number of observed orders is on average 25 OOO a year.

The occurrence: The occurrence is defined as the error on an order. On average, we have a number of annual losses of 18.2, is a probability of error on the order of 18.2/ 25 000 = 0.0728%.

The severity : severity is defined as the sum of the loss due to shifting and transaction costs. We make the following assumptions about the factors involved in the calculation of the severity.

The amount of the error (in millions of dollars)	
5	66%
15	18%
50	16%

Fig. 2. The amount of the error (expressed in millions of dollars)

The duration of correction (in days)	
0,125	66%
1	33%
90	1%

Fig. 3. The duration of error correction : the period from the date of occurrence of the error to the date of correction by the passage of a new order

The transaction costs : we assume that transaction costs are equal to 0.25% of the transaction amount. The amount of error is passed first time and a second time during the correction. The fees will be calculated by multiplying the amount of the error by 0.5%.

The rate shifts : it is about the variation of the rates observed during the duration of correction of the error.

The loss due to shift : it is calculated by multiplying the amount of the error by the rate shifts.

The rate shifts	The duration of correction (in days)		
	0,125	1	90
2%	66%	62%	60%
5%	34%	37,99%	38%
30%	0%	0.01%	12%

Fig. 4. The duration of correction

We now study the algorithm that we described in the theoretical part :

Here, the exposed objects are of the same type, that are orders of the same nature : $X_i = X$, which implies that $P_i = P\ (Exposure = Xi) = 1$.

We deduce the probability from it that the risk arises knowing that the exposure $is\ X_i$: $PS_i = P\ (Occurrence = "yes" \mid Exposure = X_i) = P\ (Occurrence = "yes") = 0.0728\%$.

The algorithm consists in realizing successively the following steps :

1. Calculate the distribution of severity $PG_i = P(Severity \mid Occurrence = "yes"\ and\ Exposure = Xi)$.

2. Sample the number of losses F_i according to binomial distribution $B(nb(X_i)\ ;\ PS_i) = B\ (25000;\ 0{,}0728\%)$.

Indeed, orders are independent and each order follows a Bernoulli distribution.

3. For each incident of 1 to F_i, sample the severity according to the PG_i distribution.

4. Sum the severities F_i.

We repeat these 4 stages 10 000 times by keeping the sums of the severity every time. We so obtain a distribution of total losses and we can deduct the VaR from it in 99,5 %.

We realized tests of sensibility in the various parameters of the Bayesian network: in every set of tests, we vary the parameters of a factor by fixing the parameters of all factors.

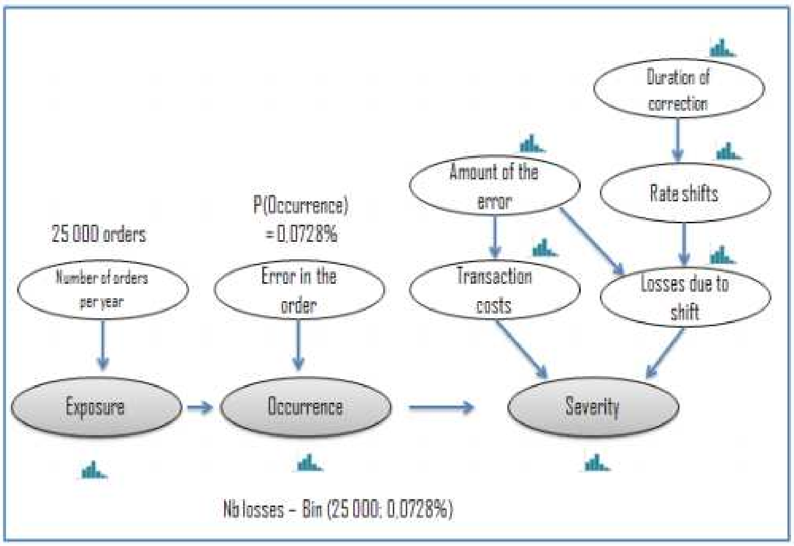

Fig. 5. Application of the Bayesian model at the risk of error in the passage of orders on an insurance company

5 CONCLUSION

We realized tests of sensibility in the various parameters of the Bayesian network: in every set of tests, we make vary the parameters of a factor by fixing the parameters of all other factors.

The Bayesian model presents many advantages :

- It allows to take into account at the same time quantitative factors(mailmen) but also qualitative factors, what do not make most of the models;
- It allows to visualize the connections of causality between variables: the aggregation of the risks is realized by the construction of networks, what avoids the estimation of correlations;
- It allows to detect factors of reduction of the risk thanks to the inference;
- The Risk management can use it to set up action plans and notice the efficiency of the latter.

The major inconvenience of the Bayesian networks is that they are long to set up because they require a detailed analysis of every risk.

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