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Optimization of the logistics function by controlling risks using influence diagram: cases of risks related to road transport

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The growth in the number of logistics platforms served by road, rail, waterway, and sea is a logical consequence of the extensive and rapid development of merchandise trade in a globalized economy. Transport and logistics are part of the same activity chain that allows goods to be transported to their destination. Dependent on the requirements of their customers and suppliers and subject to strong competition, companies in this sector must manage challenges concerning deadlines, flexibility, and diversity of goods, while handling other risks associated with transport and logistics. The Bayesian approach, proposed in this paper, covers all the steps necessary to implement decision support solutions for risk management and control, starting from the identification of risks and the preparation of intervention to the conducting of various operations in crisis In this work, the prediction and the control of the road risks are conducted using the influence diagram method, whose final objective is the optimization of the logistics function. After identifying and analyzing the different risks, the Bayesian networks (BNs) are initially used to model these risks and to prevent the various challenging situations from taking place in the logistics chain. As a second step, we use the influence diagram as a tool for the decision-making procedure. Finally, a case study is presented to highlight the substantial contribution of this tool to controlling road risks while transporting goods.

Keywords: logistics, transport, control of road risks, Bayesian networks, influence diagram, decision making.

1. Introduction

Today, all industrial or distribution companies have comparable and related strategies, characterized by phenomena that have impact on their logistical choices and, consequently, on transport. The outsourcing of logistics operations [10], the concentration of logistics sites [7], the reduction in the number of selected logistics partners, the traceability of physical flows and documents (which is a growing requirement particularly for following up remote flows), controlling the smooth running of chains and being able to provide answers to customers' questions [8], are all common elements that show the importance of logistics in optimizing transport. Therefore, as logistics performance is a function of several variables, the most traditional ones being: cost, quality, reliability, deadlines, and information, it should be noted that there are also risks related to the logistics chain, risks that can modify, or even prevent, in whole or in part, the efficient and effective flow of information, material, and products between the supplier of the supplier of the company and the customer of the customer of the company [11].

When discussing the concept of risks, financial risks are the major challenge and primary concern for companies dealing with logistical risks. It is therefore essential to stress the relative difficulty of companies in understanding, and thus in identifying the risks within the supply chain and, of course, in evaluating their consequences on the global chain [14]. However, it is no longer possible to ignore the fact that logistical risks increase with the improvement of the chain's performance. For example, the gradual inventory reduction, a reflection of a proactive strategy of tension of flows, generates contradictorily a growing risk. This risk can even increase further if the location of the warehouses is not optimal and, of course, propagate over the rest of the supply chain. Conversely, the supply chain actors, in particular industrial companies and retailers, by adopting collaborative approaches make it possible to share the risks and, therefore, to reduce them. Nowadays, the security of the supply chain is becoming increasingly important. As a result, it is not a coincidence that the supply chain risk management field is currently undergoing significant development [3].

The growth at the request of the logistics function is seen as an opportunity for transport management, because transport is one of the key management functions and, through supply chain management, business-to-business relations. However„ it becomes troublesome if logistics management focuses exclusively on information systems, ignoring less "noble" physical operations such as handling, storage, packaging, and transport [15]. With this increase in constraints and complexity, is the supply chain becoming riskier? How do companies react to face these risks? Can these risks be avoided? What is the way to eliminate these risks? Do managers prefer to manage these risks independently, or in cooperation with their industrial partners?

To answer the above questions, our study will seek to understand, analyze and control the risks associated with the logistics function. To do this, and as the answer to all those questions formulated into a decision problem, we will inventorize, prioritize, and quantify these risks using a BN, and present the decision subject using an influence diagram, while optimizing a utility function quantified by satisfaction. The case study, presented in this paper, focuses on the management of road risks during transportation, in order to show how to control and manage the risks associated with the logistics function.

2. Logistic risks

The development of commercial networks creates a variety of value-added logistics management needs and results in a large number of individual trends of logistics and supply chains. Understanding a logistic typology is a complex task. In view of a large number of factors that enable to characterize logistic activities, these logistic activities are divided into four categories for better understanding. Those categories are: industrial logistics, distribution logistics, port logistics, transport and auxiliary services.

The main logistic activities are shown in Fig. 1. Each activity has associated risks, the main ones being

- Risks specific to different activities: noise, chemical pollution, machinery, nature of manipulated products, disorder and mental workload.
- Risk of allergy.
- Mechanical risks (single-story, fall, shock).
- Risks of movement and displacement (pallet trucks, trolleys, etc.).
- Risks of falling from height or single-story structure.
- Risk of specifics of a load to be handled (large size, difficulty in gripping, lack of stability, unequal distribution of the load).
- Insufficient illumination and visibility when picking goods.

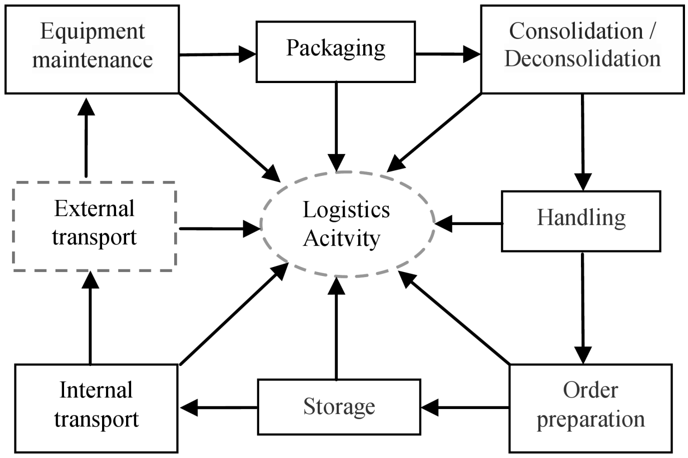

Fig. 1. Various activities associated with the logistics function.

- Risk of collisions between machines and pedestrians.
- Risk of jamming or crushing at the filling/loading station.
- Risk of fire, explosion, flooding, or electrocution.
- Risk of accidents related to the insufficient organization of movements and displacements.
- Risks of accidents due to lack of vehicles' maintenance.
- Risk of accidents related to communications during movements and displacements.
- Risks of accidents due to inadequate qualifications and training.
- Risks of aggression.
- Risks of stress.

In logistics platforms, manual handling and load-carrying are the leading causes of accidents at work, followed by single-story accidents and the use of mechanical machinery. When the work takes place under time pressure and/or under rigorous organization, it is accompanied by repetitive tasks and gestures which cause uncomfortably confining, restrictive and difficult work situations. In addition, working in cold, constraint movements and displacements, and stress all favor further development of these situations.

Uncertainty, threat, vulnerability, and danger-all these terms revolve around a central notion that needs to be understood to better control the risk. Today, the risks are more numerous, change form, combine and have the capacity to reinforce each other. The mastery of risk management and risk control become even more necessary as they are directly related to the performance of the company and the responsibility of the manager. Basically, a risk is the consequence of a danger, itself intrinsic characteristic of a product, a situation, or an act. Moving from uncertainty to risk, the probability of uncertain event is difficult and sometimes impossible to define. And, consenquently, it is diificult to anticipate and manage constraints. By contrast, the probability of risk event is definable, therefore we can predict the onset of risky event and apply various methods of control (preventive measures) to prevent it. Switching from one to the other becomes a real challenge.

Defining and apprehending risk is a difficult task [6]. So, for ease of definition, we can then go through the concepts of threat and vulnerability, which additionally introduce an operational character to a good apprehension of risks. In this case, the risk must be interpreted as the result of applying a threat to vulnerability. Wanting to treat risks in their entirety is illusory, as well as believing that risk management has a term. Hence, a thoughtful and structured risks management is required. It must adapt to all types of businesses, from small and medium to multinational.

Assess the risk: the first benefit of assessing risks is to be able to prioritize them by defining criticality of the risk which is defined, as a first approach, according to the probability of occurrence and its severity [5]. An action plan is then possible.

Treat the risk: from a methodological point of view, whether to be upstream or downstream of a risk, two axes of work are offered to us: one in a prevention framework, to intervene on the probability of occurrence of the risk, whereas another one is in a correction framework, to act on the gravity component.

Risk analysis, a crucial step in choosing framework, must be well prepared. The quality approaches and the skill approaches, although they are not the only approaches, when combined they constitute operational responses to the risks.

3. Bayesian networks and influence diagrams

Probabilistic graphical models, such as BNs and influence diagrams [17], have been widely used to solve various problems (e.g., identification, classification, fault prediction, risk analysis). These models are characterized by their ability to process uncertain information and to represent the interdependencies between different variables of a given problem. The advantage of probabilistic graphical models is their interesting graphical representation of models that is easy to understand and interpret. Reasoning from probabilistic graphical models facilitates the handling of problems such as prediction or identification. In addition, it is known that probabilistic risk analysis has many advantages because it enables evaluating the probability of failure of a complex system so that its weak points can be identified [1, 4, 13]. Another advantage of probabilistic graphical models concerns the various tools developed which participate in and which facilitate the designing a model representing a given problem. In this paper, we use the GeNIe software [9] to develop a road risk analysis model for optimizing the logistics function.

3.1. Bayesian networks

In Bayesian methods, *a priori* information, likelihood, and *a posteriori* information are represented by probability distributions. An *a priori* probability represents the probability distribution of knowledge or belief about a subject or variable before the parameter it represents is observed. The likelihood is a parameter function of a statistical model, reflecting the possibility of observing a variable if these parameters would have a value. *A posteriori* probability is a conditional probability on the collected data by combining *a priori* probability and likelihood via the Bayes theorem [2].

A BN can be defined as a probabilistic graphical model. However, it may also be referred to as probabilistic network or belief network.

A BN is a complete tool allowing the visualization of variables and their dependency (or dependencies). It also allows describing the operation of a system quantitatively by means of various calculations of probabilities related to the variables of the system. Generally, random variables are modeled as nodes. We can then draw an arc between certain variables of the system. Plotted arcs can report a phenomenon of causality between related variables (causal networks).

The fact of indicating an arc between two variables implies a direct dependency between these two variables: one is the parent and the other the child. It is necessary to provide the behavior of the child variable in view of the behavior of its parent (s). For this, each node of the network has a table of conditional probabilities. A conditional probability table associated with a node makes it possible to quantify the effect of the parent node (s) on this node: it describes the probabilities associated with the child nodes according to different values of the parent nodes. For root nodes (without parents), the probability table is no longer conditional and then fixes probabilities *a priori* concerning the values of the variable.

BNs prohibit child-to-parent dependencies. Thus, the set of variables and arcs will form a directed (the arcs have meaning) and acyclic (no cycle in the graph) graph.

Formally, a BN [12] is defined by:

- an acyclic oriented graph G, $G = (V, E)$, where V is the set of nodes of G, and E is the set of arcs of G,
- a probabilistic space (Ω, Z, P), with a non-empty finite set, Z a set of subspaces of Ω, and P a probability measure on Z with $P\ (\Omega) = 1$,
- a set of random variables associated with the nodes of the graph G and defined on (Ω, Z, P), such that:

$$P\left(V_1,\ V_2, \ldots, V_n\right) = \prod_{i=1}^{n} P\left(V_i / C\left(V_i\right)\right), \tag{1}$$

where $C(V_i)$ is the set of parents (or causes) of V_i in the graph G.

3.2. Influence diagrams

Influence diagrams are efficient modeling tools for representation and analysis of decision making (Bayesian) under uncertainty. Influence diagrams provide a natural representation for decision making with the least amount of uncertainty and confusion for the decision maker. The solution to a decision problem is to determine an optimal strategy that maximizes the expected utility for the decision maker and calculates the maximum expected utility to adhere to this strategy.

An influence diagram is a type of causal model that differs from a BN. A BN is a probabilistic network for reasoning under uncertainty, while an influence diagram is a probabilistic network for reasoning about decision making under uncertainty. An influence diagram is a graphical representation of a decision problem involving an order between decisions and observations. Similar to BNs, an influence diagram is a compact and intuitive probabilistic representation of knowledge (a probabilistic network). It consists of a graphical representation describing dependency relationships between variables, in case decisions need to be made, and a priority indicating order on decisions and observations. It also represents a quantification of the strengths and/or weaknesses of the decision-maker's dependency relationships and preferences. An influence diagram can be considered as a BN to which decision variables are added, utility functions indicating the decision maker's preferences, and priority control (Fig. 2).

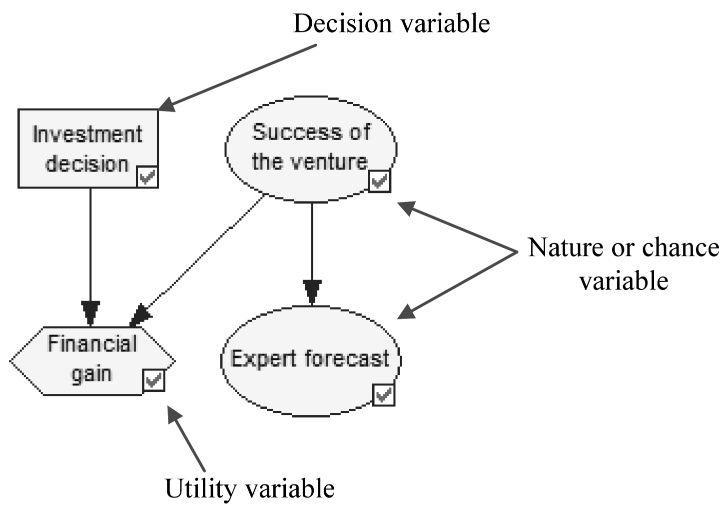

Fig. 2. Graphical representation of the different types of variables by GeNIe software.

The influence diagrams contain various kinds of variables:

- Chance nodes: correspond to the variables of the problem, except decision variables and utility variables. Arcs towards chance nodes mean that the probability distribution of these variables is a function of their parents.

- Decision nodes: correspond to the decision variables of the problem, they represent the variables that are under the control of the decision-maker and model the available alternatives of decision for the latter. Arcs of chance nodes towards decision nodes indicate that the probability distribution of these chance variables will be affected by the decision. Arcs of decision nodes towards chance nodes mean that the probabilities of these chance variables can be affected by the decision. If the influence diagram contains more than one decision node, these nodes should be controlled in a decision order.

- Utility nodes: correspond to value nodes (as gain nodes), which measure the desirability of the results of the decision process. The utility quantifies each of the possible combinations of results of the parent nodes.

A primary and common element for all decision problems, and without which no decision can be made, is preference. Very often, it can be based on an objective quantity, such as material usage, factory performance, or financial gain. Typically, however, decision problems involve quantities that have no apparent numerical measurement, such as health status, or client satisfaction. Another complication is a set of probably contradictory attributes, such as price and quality. Even if a numerical measure of results quality is available, such as the case of financial gains and losses, it may not reflect good decision-making preferences in the presence of risk. Decision theory presents a measure of preference, known as utility. Utility is a function mapping the attributes of the possible outcomes of a decision process to the set of numbers. Utility is subjective: the various decision makers facing the same scenario may make choices differently because of their different preference structure and different service functions. A service function for any decision problem must be obtained from a decision maker. It should be noted that variables measuring utility are always continuous: they can assume all the values within a continuous interval.

The probabilistic inference in the influence diagrams involves propagating the evidence observed in the graph, by calculating the posterior probabilities of the hidden variables according to the values of the observed variables and obtaining the value of the utility for each possible decision [16]. Influence diagrams offer a lot of advantages. The three main benefits are ease of use, representation and modeling of knowledge, and uncertainty management.

4. Assessment of risks related to road transport

One of the most obvious manifestations of logistics activities is the growth of transport of goods due to the expansion of world trade. The industrial globalization, including the activities of planning, procurement, manufacturing, and marketing, has resulted in greater trade complexity and increased development of transport networks. Goods could be transported by several modes including roads, sea, air, rails, and rivers. Among these modes, the decision to use roads in the transport of goods is the result of a convergence between the main characteristics of this mode of transportation and the expectations and motivations of customers.

What is needed to control the risks associated with this mode of transport is to define a risk assessment indicator, with an evaluation mechanism to measure the overall safety of a road transport mission. Good indicators can provide better information on the level of risk. For example, a BN can be used to analyze and diagnose the various risks associated with road transport to identify and quantify the most important indicators, and to determine the relationships between these indicators (causes-consequences). Data obtained from a survey and experts' evaluation represent the *a priori* probabilities for the BN nodes.

4.1. Modeling

4.1.1. Definition of the network structure

The action plan to prevent road risk in the company is based on the highlighted risks. A part of the actions to be implemented concerns the management and organization of human and material resources. Preventing road risks consists of acting on [18]:

Displacements and infrastructure: management and overall scheduling of displacements (in time, duration...) are key points of road risk reduction. Any displacement is scheduled and prepared in advance by the company, and not at the last moment once on the road. Therefore, it is necessary to organize, within the company itself, appointments, tours planning, choice of roads, appraisement of traveled distances, and break times, emergency management, and delays.

Vehicles and maintenance: The vehicle for professional use must be adapted to both the displacement and the mission to be carried out. It must be arranged and equipped according to the needs of people and/or loads to be transported. Furthermore, there must be a separation between the passengers' compartment and the volume used for loading (transport of materials, products, tools...). The vehicle capacity and power, essential characteristics, allow transporting loads without any risk. Any overloading is an important factor that could sensitively increase the risk.

Communications during displacements: The mobile phone has become so familiar that the company must organize its use in a professional context, especially on the road. Hence, it is necessary

Table 1. Risks associated with road transport activity.

Risk	Code	Causes	Code of causes
Vibration	Vib0	Driving on deformed roadway	Vib011
		Driving on worksites	Vib012
Noise	Noi0	Driving with open window	Noi021
		Noisy loading	Noi022
Chemical risks	Chem03	Urban pollution	Chem031
		Exhaust gas	Chem032
		Emanations	Chem033
		Vapors	Chem034
		Leaks from loading	Chem035
Repetitive Gestures	ReG0	Clutching/Declutching	ReG041
		Change of speed in urban traffic	ReG042
Extended Static Position	ESP0	Long journeys	ESP051
		Long waits	ESP052
Stress	Str0	Delivery time constraints	Str061
		Time constraints of appointments	Str062
		Traffic density	Str063
		Damaged road	Str064
		Rain	Str065
		Fog	Str066
		Slippery road	Str067
		Vehicle in bad condition	Str068
		Noisy loading	Str069
		Long waits	Str0610
Heat	Hea0	Driving in summer sun	Hea071

to put in practice a communication protocol that allows employees to keep in touch with their company and their customers while on mission, without endangering their safety on the road.

Skills and training: Vehicles used at work have very variable characteristics and require the acquisition or mastery of specific skills. These can be commercial vehicles, carrying heavy loads, or minibuses, transporting several employees of the company. In addition, performing tens of thousands of kilometers per year, under some difficult conditions (rain, black ice, poor visibility...), also requires special skills. Beyond the risk of corporal accidents, the driving activity can give rise to many other risks. They should not be neglected in a prevention approach, especially in sectors where driving is an essential task of the professional activity such as logistics (see Table 1).

All these variables represent the nodes of the causal network, the connection by arcs between the causes and the consequences of the various risks facilitates the dialogue between modeler (expert) and user (business leader), and the basis of this modeling is the theory of graphs. This is a qualitative risk assessment (see Fig. 3).

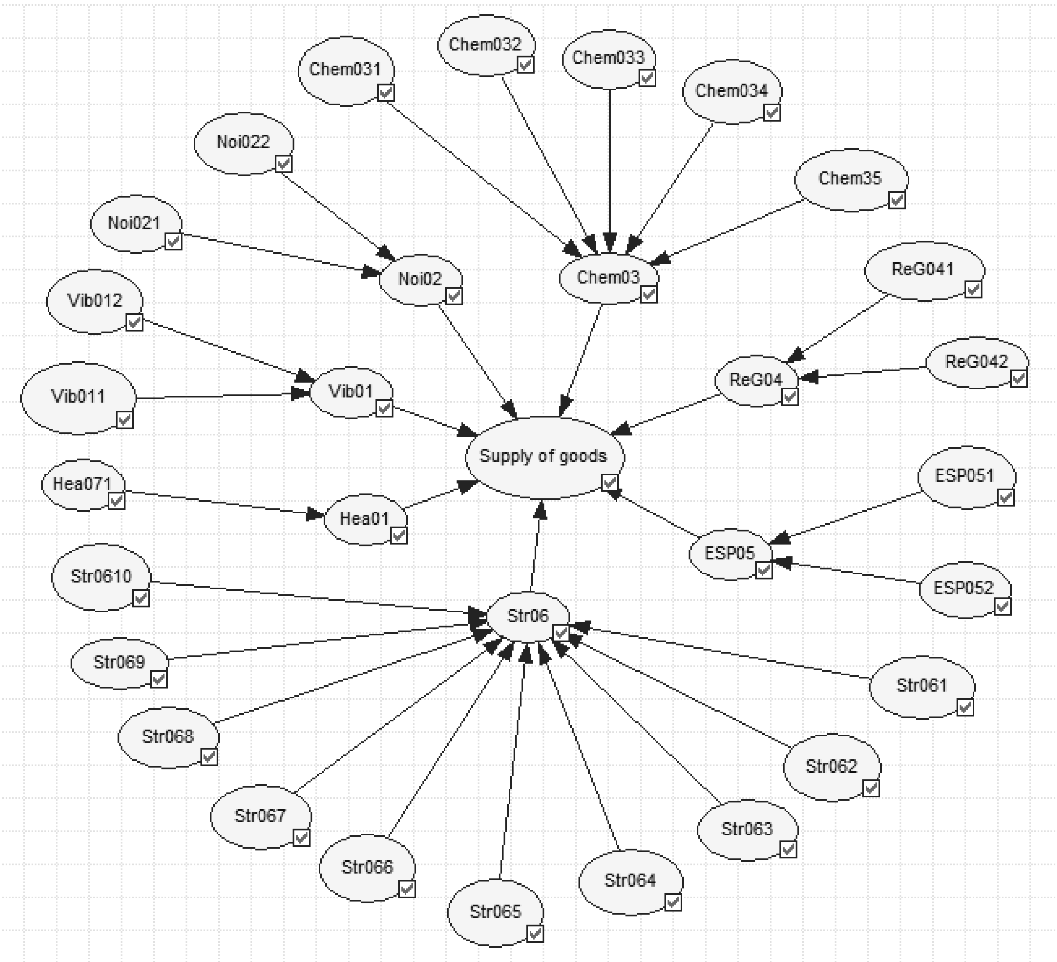

Fig. 3. Causal network modeling of the influence of different risks on supply.

4.1.2. Application

In this paper, we deal with the case of a supply of goods between two harbor companies in Algeria (Fig. 4), the harbor company of Annaba, EPA (extreme east of Algeria), and the harbor company of Skikda, EPJ (located in eastern Algeria). Through an evaluation of the risks related to the transport of goods, we evaluate the influence of these risks on the supply activity.

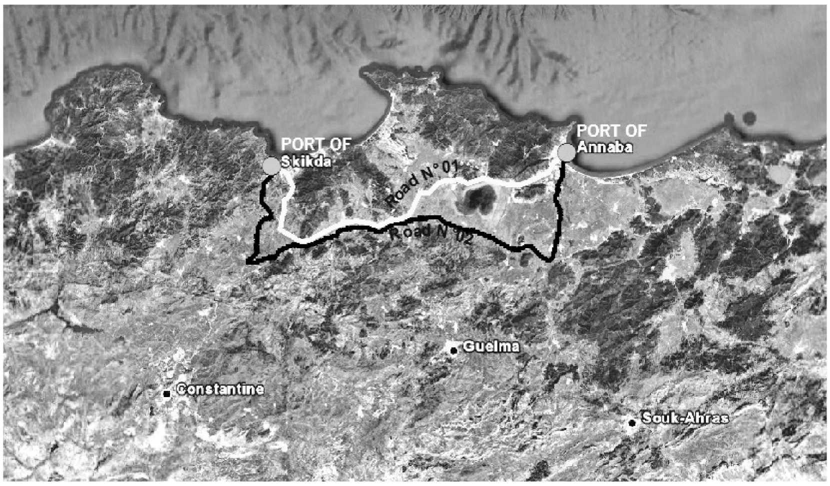

Fig. 4. The two roads connecting the two harbor companies.

4.1.3. Setting network parameters

Network parameters are given by the *a priori* probabilities of each input variable or node (see Table 2). The data processed in this case study are binary true or false.

Table 2. Variables of the model and *a priori* probabilities.

Causes	Code of causes	*A priori* probability
Driving on deformed roadway	Vib011	9.5 e-05
Driving on worksites	Vib012	1.01e-06
Driving with open window	Noi021	1.05e-10
Noisy loading	Noi022	5.05e-06
Urban pollution	Chem031	1.02e-06
Exhaust gas	Chem032	1e-10
Emanations	Chem033	1e-10
Vapors	Chem034	1e-10
Leaks from loading	Chem035	1e-10
Clutching/declutching	ReG041	1e-10
Change of speed in urban traffic	ReG042	1e-10
Long journeys	ESP051	1e-10
Long waits	ESP052	1e-10
Delivery time constraints	Str061	1e-10
Time constraints of appointments	Str062	1e-10
Traffic density	Str063	1e-10
Damaged road	Str064	9.5e-04
Rain	Str065	1e-10
Fog	Str066	1e-10
Slippery road	Str067	1e-10
Vehicle in bad condition	Str068	1e-10
Noisy loading	Str069	1e-10
Long waits	Str0610	1e-10
Driving in summer sun	Hea071	1.02e-06

Goods are transported by semi-trailer traveling east-west between EPA and EPS over a distance of 135.8 km (yellow line in Fig. 4), of which 42 km represents a degraded segment. The risks relating to the case study are listed and recorded in the safety sheets of the Annaba harbor company (Table 2).

4.2. Inference

The combination of the graphical structure and the associated probabilistic structure will help to create a BN. The essential use of BNs is called inference, which consists of calculating conditional probabilities of events connected to each other by cause-and-effect relationships. Inference in a network of causalities consists of propagating one or more certain pieces of information within this network, to deduce how the beliefs concerning the other nodes are modified. Figure 3 represents the BN that models the influence of road risks on the supply of goods. In the case where there is no prior information on the variable, its probability will be estimated at 0.5.

The intended *a posteriori* probabilities are given in Table 3.

Table 3. *A posteriori* probabilities.

Variable	Probability
Supply of goods	0.99933368
Vibration	8.5501e-005
Noise	4.7975053e-006
Chemical risks	1.006e-006
Repetitive gestures	1e-006
Extended static position	1e-006
Stress	0.00057204824
Heat	1.02e-006

5. Discussion

From the diagram in Fig. 3, we notice that the variables of the BN are independent, which makes easier the inference in the network, on the one hand, and allows the evaluation of the probability that the supply is assured without any *a posteriori* information, on the other hand. Table 3 shows that supply will be assured with a probability of 99.933368%, while the main causes of this probability are the availability of the road which causes stress and vibrations. From the risk assessment by this BN (Fig. 3), it can be seen that the two main risks are stress and vibrations. Similarly, and by inverse hierarchy, we can conclude that driving on deformed roadway represents the main cause of risks.

Now, to show the contribution of influence diagrams, an elementary example is presented below (Fig. 5).

The *a priori* probabilities and the *a posteriori* probabilities of this example are given in Table 4.

From the diagram in Fig. 5, we notice that the variables of the Bayesian network are independent, which makes easier the inference in the network, on the one hand, and allows the evaluation of the probability that the supply is assured without any *a posteriori* information, on the other hand. The Bayesian network in Fig. 5 shows that supply will be assured with a probability of 99.913819%, while the main causes of this low probability are the availability of the road, and the probability of an accident occurring.

From this risk assessment by this Bayesian network (Fig. 5), it can be seen that the two main risks are the accident and road availability. Similarly, and by inverse hierarchy, we can conclude that telephone calls represent the leading cause of accidents, and the *a priori* probabilities of the

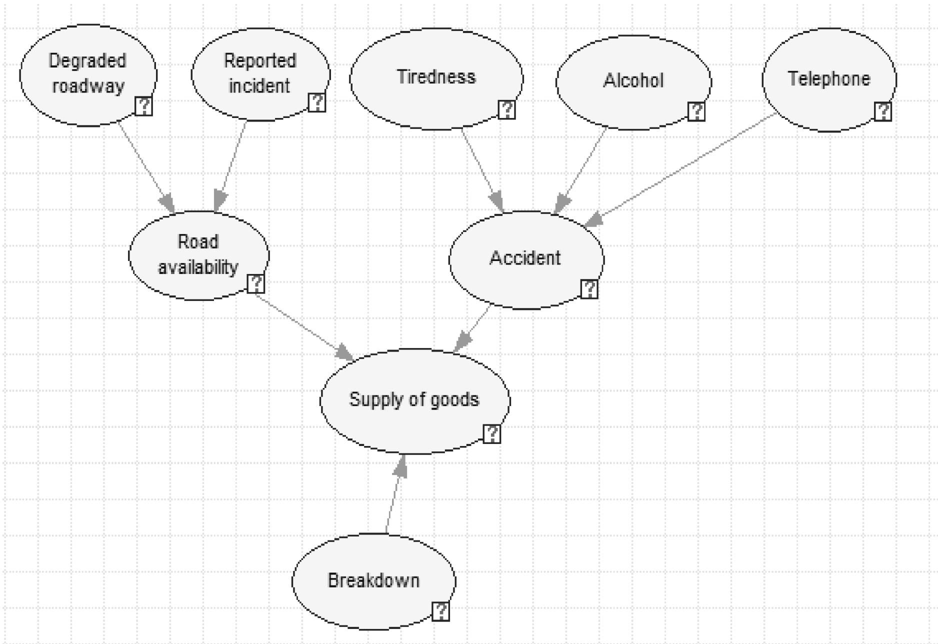

Fig. 5. Bayesian network modeling the influence of five risks on supply.

Table 4. *A priori* and *a posteriori* probabilities.

Variable	*A priori* probability	*A posteriori* probability
Supply of goods	–	0.999984124
Breakdown	4.5e-006	–
Road availability	–	0.9991449
Accident	–	2.2100721e-006
Degraded roadway	0.00095	–
Reported incident	1.02e-06	–
Tiredness	6e-06	–
Alcohol	1e-010	–
Telephone	5.05e-06	–

reported incident variable are equal since there is no *a priori* information on events on the road. However, the strong belief in roadway degradation did not significantly influence the probability of road availability.

From this analysis, the corrective actions will be concentrated in a certain way on the telephone variable (true for 5.05e-06) by awareness campaigns and on the variable availability of the road (true for 0.999984124) by route planning. But what is the impact of these actions on the supply function, and can we quantify it? Why give preference to this or that action? Influence diagrams are used to anticipate decisions and move from an uncertain decision-making environment to a more secure one.

6. Use of utility function and decision tree to optimize the logistics function

The logistics function is represented in this case study by the supply of the goods. In decision-making by a manager regarding the planning of the road that must be traveled by the driver, to identify the problem of road degradation, the cost of a supply delay, an accident risk, and a risk of failure, should all be converted by a utility function. This function has been used for decades in the management of financial risks. For purposes of decision-making, the utility will be calibrated with consideration of all the preferences of the manager, or planner. Given this situation, the solution must be given in a way that lowers the probability of risk occurrence and increases the utility function.

A BN, which calculates the utility function measured by a discrete variable, which is the satisfaction of the customer or the supplier of the supplier, plus a decision variable are illustrated in Fig. 6. This network is called the influence diagram.

Two things are considered here: the decision node "course alteration" to another road like the national road (red line in Fig. 4), and the utility node that measures satisfaction. This network also allows the re-evaluation of the supply function with uncertainty measurement. On the influence diagram in Fig. 6, our decision-making is certain, it is 45%, and the probability that the supply of the goods is insured increases to 99.999329%. There are links from course alteration and supply of goods to satisfaction, and the ideal is to ensure supply without changing the road (utility = 100), followed by when the supply will be assured even with a change of road (utility = 0.79999463). Finally, it is more penalizing if the goods do not arrive in time (utility = 0).

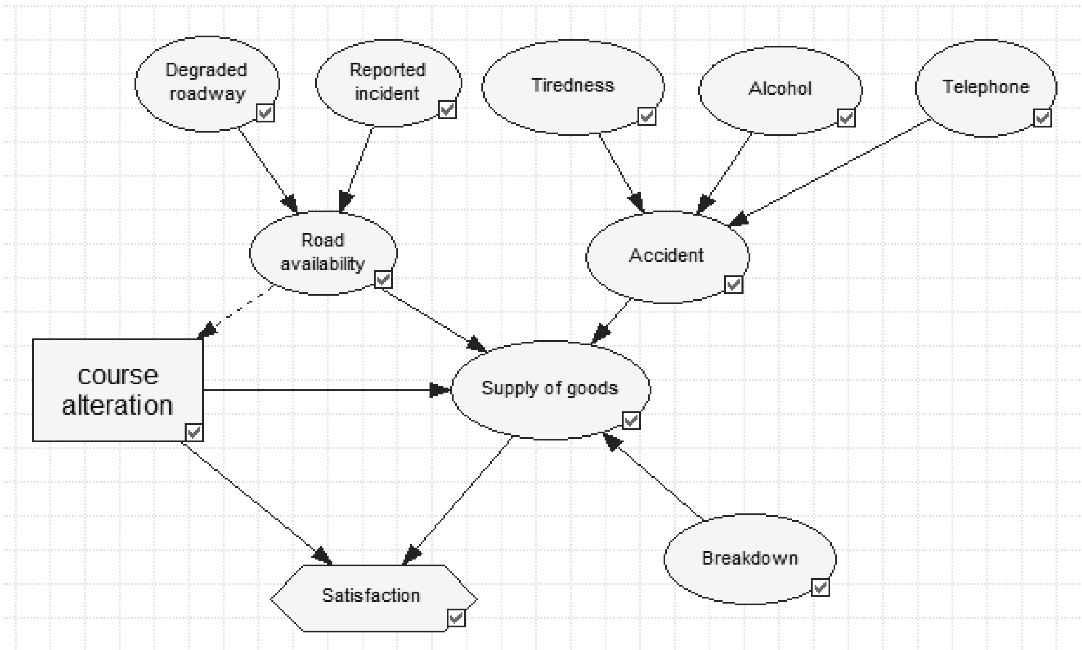

Fig. 6. Influence diagram for the optimization of the logistic function.

Bringing the perception of different risks from the various combined parts into a decision topic is a task that is neither easy nor simple. However, applying these tools will help make subjects more clear, and show more objectivity. The effects of measures and corrective solutions are evaluated and mastered with these tools before practicing them.

Sensitivity analysis:

Sensitivity analysis is carried out by investigating the effect of variables' probabilities on the *a posteriori* probabilities of the variable "supply of goods". Highly sensitive parameters affect the reasoning results more significantly. Identifying them allows for a directed allocation of effort to obtain accurate results of an influence diagram. Searching the most important parameters in the model and giving them a good precision allows better modeling.

Suppose that we are uncertain as to the actual probability of the supply of goods by the company. Believing that the nominal value of 0.5 is approximately right, we feel that it can be as low as 0.3 and as high as 0.7. To express this, we will add "sensitivity" of three states: low, nominal, and high. As this "sensitivity" is regarding the probability of "supply of goods", we need to define a relationship between the "sensitivity" node and the "supply of goods" node. The low, nominal, and high values should be entering for the probability of outcome supply of goods in the conditional probability table of the node "supply of goods" (Fig. 7).

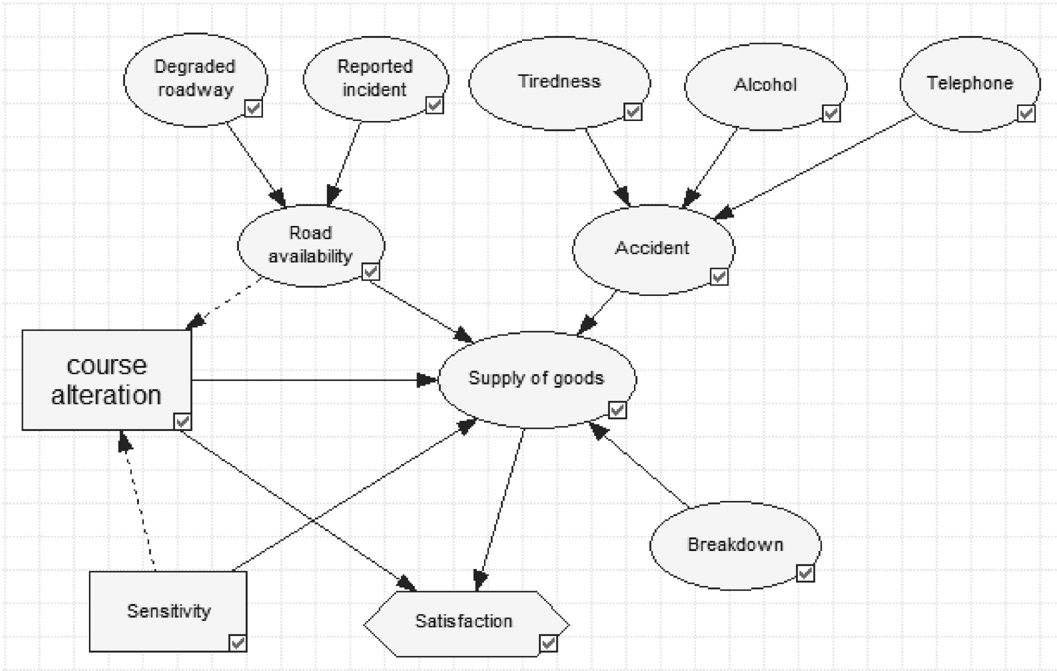

Fig. 7. Sensitivity analysis diagram.

When the road is not available and for the high sensitivity the *a posteriori* probability of the decision node "course alteration" is equal to 0.55999624. Expected utilities for different policies of sensitivity are: low = 0.99934342, nominal = 0.99948023 and high = 0.99961705. We can see that even the most optimistic value of the probability of "supply of goods" acts on "course alteration" as an attractive option, so our decision is sensitive to the value of the probability of supply of goods.

7. Conclusion

This paper discusses and presents an alternative for risk analysis, which uses a directed acyclic graph or a network of nodes linked by arcs representing a cause-effect, or risk-damage scenario, and which allows the determination of the effects of damage by manipulating the probabilities of continuous and discrete stochastic variables. The advantages of the method are its clarity and flexibility in introducing all kinds of variables and their effects taking into account their ranges of uncertainty. Clarity is achieved by obtaining and directly reading the results of the distribution of each node. This approach can use the risks and effects on the environment to integrate the notion of sustainable development, but with significant uncertainty regarding this issue, especially at the level of input parameters or *a priori* probabilities.

The results, found by the modeling using this type of tool, showed that, in the presence of several risks related to transport by road of goods, the logistics function is threatened by several handicaps. However, the knowledge of the consequences of the different risks, in advance, gives the possibility of programming corrective actions to control, minimize or even eliminate these risks. The difficulty of using these tools lies in the variety of goods and their specificities (fragile, dangerous...), the *a priori* information on road traffic, frequent incidents on these roads, and their state, all illustrated and discussed in the case study. The definition of network parameters by an expert, or by experienced feedback is the platform of the network.

An influence diagram is very interesting because it allows studying the different reactions of a system modeled by BNs depending on the actions taken on the system. Thus, through the utility, it is possible to compare the performance of this or that action on the system. In addition, it is possible to optimize the various decisions to be made on the system: what decision to choose, and when? In our case study, we showed that a simple decision (change of road) gave us the opportunity to increase the probability of securing supply. With the influence diagram presented in this paper, it is possible to anticipate decisions in a certain environment, or even justify the decisions taken by the optimization of the utility function (customer satisfaction).

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