MULTI-AGENT FRAMEWORK FOR HAZARDOUS GOODS TRANSPORT RISK MANAGEMENT

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ABSTRACT

It is difficult to prevent accidents in the transport of hazardous goods, so the development of strategies for managing crisis situations and the optimization of action plans are important. The crisis situation is a continuous event in time when its evolution is unpredictable because it depends on a whole of complex factors resulting from the environment of the crisis. Decision making in crisis situation is complicated because it depends on a set of distributed actors in the environment where each one with its own perception of the problem. The continuous evolution of a crisis situation and the need of cooperation between the actors make the optimal decision making difficult. The aim of this work is the development of decision support system “DSS” to assist actors in crisis situation in order to anticipate the evolution of an incident and to determine the effectiveness of strategies used and the allocated material. The proposed DSS is based on a multi-agent system “MAS” used for the reproduction of collective and multi-actor decision-making scenarios. Our system receives accident’s alerts from GOST 1 “platform for tracking hazardous material containers in real time”. This paper presents the proposed model for managing the risk of transporting hazardous goods.

KEYWORDS

DSS, MAS, hazardous goods, risk management.

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1 GOST : Géo localisation Optimisation et Sécurisation du Transport des conteneurs
INTRODUCTION

Historically humans have been exposed to various types of danger from many sources such as natural hazards or the dangers resulting from human activity, which presents a potential source of damage. In France the transport of goods is an important economic activity in the metropolitan area of Le Havre, every commodity requires compliance with a set rule during transportation.

The transport and storage of hazardous materials require more care for the danger they pose to people and the environment. The occurrence of accidents involving transport of hazardous materials generates unpredictable serious consequences requiring effective interventions forced by time.

In a crisis, uncertainty and lack of information on the characteristics of the hazardous material transported also the nature of the accident site and the quantity shipped is a major handicap for the choice of the adequate plan of intervention.

Several studies have been made for the prevention of the risk in transporting hazardous materials and the mastery of a crisis. SIGRIMAS, the geographic information system of the major risks for the Seine Estuary is developed by the direction of prevention of main risks “DPRM” It aims to detect vulnerable areas based on GIS to develop a risk management policy [Malet and Li, 03].

Other work has focused on the monitoring of hazardous materials transportation “HMT” in real time as the MITRA project "monitoring and intervention for the transportation of dangerous goods" which aims to develop a prototype for the monitoring of HMT in Europe. The innovation of this system is manifested in the use of new communications technology for the traceability of HMT to inform civil safety centers and provide them with proven information on the characteristics of hazardous materials. This project has determined the relevant parameters to ensure more effective interventions [Planas, 07].

Routing transportation of hazardous materials is recognized as a critical decision for the mitigation of risk. The purpose of this system is the use of techniques of operations research for planning transportation of hazardous materials and the search for alternative routes. Also the system allows the efficient deployment of the teams of action in crisis situation to intervene at convenient time and specifies location of evacuation routes to shelters and estimate the time required for evacuation [Konstantinos, 08].

The aim of this work is to design DSS based on a MAS to assist experts in decision making in crisis situations caused by an accident of HMT. The
system retrieves the alerts from the GOST platform that will locate in real
time and determine the type of hazardous material transported. It follows an
analysis of information retrieved from the accident environment and all
existing resources in the area of the accident. The system will propose a
subsequent intervention scenario taking into account the evolution of the
 crisis. We are particularly interested in the risks of storing hazardous
materials and compliance with rules of segregation between different type’s
hazardous goods. This work is a contribution of the artificial intelligence in
general and the multi-agents in particular to the risk management. This paper
details the architecture of our system, components of the MAS and the
process of reasoning used to solve problems by different actors intervening in
crisis.

**BODY OF THE PAPER**

**RISK**

The risk is taken into account exposure to a danger inherent in a situation or
activity. It is also defined as the probability of occurrence of the event and the
magnitude of its consequences. The science that studies the risk is Cindynics.

Risk management in the hazardous goods transport is to follow a set of
rules when loading and unloading of hazardous materials also during the
construction of transport vehicles. The HMT is affected by speed restrictions
and road use also risk management depends mainly on the human factor
which is manifested in the special training of stakeholders in the field of
HMT.

Risk perception is an important factor in determining the vigilance in crisis,
several techniques for calculating risk have been proposed:

- The quantitative approach: also called the technical risk calculation is
to quantify the risk by the product of the probability of occurrence of an
incident and the extent of its consequences. We use the following
formula :

\[
R = P \times C
\]

- \( R \) : calculated risk
- \( P \) : the probability of occurrence of an incident
- \( C \) : the magnitude of the foreseeable consequences.
• Qualitative approach: The calculation of the risk is also based on the quantification of the qualitative parameters of its principal modules (probability of emission, exposure to the danger, consequences) by the attribution of the qualitative appreciations to each parameter [Dufour, 02].

• Hybrid approach: consists in the combination of the above techniques in order to enjoy the simplicity of the qualitative approach to determining the important modules in risk analysis in order to treat them using the quantitative approach.

Crisis situation

The occurrence of an accident of HMT generates a crisis situation during which the foreseeable consequences of this incident are concretized. There exist two axes for the definition of a crisis situation the first describes it as an event:

• A crisis or critical incident is simply a sudden and unexpected event with an institutional risk requiring rapid decision-making [Pachall, 92].
• A crisis is sudden and unexpected; it may cause disruption of operations and presents financial and reputational risks [Coombs, 07].

The second describes the crisis as a process:

• A crisis is not an event but a process extended in time and space [Shrivastava, 95].
• The crisis is a process of incubation that starts long before its outbreak. [Roux-Dufort, 07].

Overall architecture of the system

The proposed decision support system to assist stakeholders in crisis consists of the following tools:

• GOST platform
• Geographic information system
• Case base
• Multi-agent system
• Knowledge base.
The following diagram describes the overall architecture of the system:

**Figure 1. The architecture of the proposed DSS**

![Architecture Diagram]

**GOST system:** GOST is a platform for tracking hazardous materials transportation in real time. It uses new technologies of information and the communication and it provides to the system alarms of accidents of HMT in addition to the necessary information for its localization.

**Geographic information system:** The coordinates provided by the platform GOST are used by the GIS to determine the parameters that characterize the place of accident such as the nature of landforms in the region is an important factor in judging the accessibility and choice of materials intervention, also for determining the density of population in the affected area.

**Case base:** The base case represents the archiving of crises already addressed and solutions have been used for solving these problems. The intended use of the case base is the reuse of the solutions of similar situations to limit the time for proposing a scenario of effective interventions based on a case-based reasoning.

**Multi-agent system:** It is the core of our system of decision support and consists of a set of agents representing the various stakeholders in crisis. It is based on artificial intelligence techniques to reduce the complexity of solving a problem by dividing the necessary knowledge to a subset of agents and coordinating their activities [Ferber, 95].

**Knowledge base:** It is an internal database in multi-agent system; it contains all the knowledge gained by the agents forming the system for solving problems.

**structure of the multi-agent system**
The proposed MAS is composed of a set of heterogeneous agents representing constituents and stakeholders in a crisis situation, these agents are divided into two groups, one composed of reactive agents representatives environment of the accident and the consequences of a crisis situation (e.g., the temperature agent, wind agent, fire agent). The second group of agents representing all the cognitive agents of the system (e.g., the agent representing the prefecture agent, fireman agent), the following class diagram shows the specialization of the agent class of the MAS:

![Figure 2. Class diagram of the specialization of the class Agent](image)

The proposed MAS is composed of several agents forming hierarchically structured groups. There are two types of agents within one group, the following figure describe this organization:
• The leader of the group: is a heavy cognitive agent has all the information necessary to manage its group (eg the number of available agent, the specialty of each agent, the capacity and performance of each agent).
• Simple agent: is a light cognitive agent specializes in the creation of a precise spot, such as a firefighter officer responsible for collecting hazardous materials.

Changing role of agents

The leaders of groups involved in two-level systems the first level is manifest in its communication with the other agents within the group they supervise and the second level is characterized by participation in the process of decision making in the deliberative group. The deliberative group consists of a set of heterogeneous agents to judge the validity of the action plan proposed by the expert staff, the following diagram "cheeseboard diagram" (AGR method - Agent Group Role) of the participation of agents in different levels of the system:
Case based reasoning CBR

In crisis, decision making in the shortest time is vital, in this system we use a CBR which is reasoning by analogy. This reasoning approach reproduces the process used by humans to solve problems. The case-based reasoning in the proposed system is dynamic and based agents. The overall CBR process begins by searching for similar cases in the current situation and then proceeds through the screening of cases found in the choice of most similar cases using the algorithm of the nearest neighbor. Then we adapt the solution found for the generation of a new solution. In the end if the new solution is validated the solution it is added to the base case, the following diagram shows the concatenation of these steps:

Figure 5. Overall process of case-based reasoning
Structure of case base
To optimize the search of similar cases we use several case bases (nine case bases corresponding to the nine classes of hazardous materials defined by the UN). The use of several case bases reduce the number of case stored by category of dangerous goods and decreases the time of exploration of the base. The following diagram shows new the bases of cases used:

Figure 6. The nine case bases

scenario of solving a problem
In case of the HMT accident the platform GOST send an alert to the MAS. The prefecture agent supports the collection of information on the accident environment using the GIS and transfers these settings to the expert agent in order to propose an intervention plan. The expert agent researches the case base, and proposes a solution to the prefecture agent. For the validation of the proposed solution a collective decision by the chief agents of various groups to validate the availability of resources is necessary to implement the plan.

CONCLUSION
In this paper we have presented our approach to designing a DSS in crisis situations. The proposed DSS is based on the use of artificial intelligence techniques to solve complex problems that change over time. The contribution of the use of the MAS is seen in his adaptation for the treatment
of problems involving distributed collaborative decision-making and multi-actors also the degree of autonomy to adapt agents to solve new problems.

The implementation of this system will allow actors of intervention centers in crisis to have a tool that will provide proved information for each type of hazardous material and also propose an action plan to improve team effectiveness response to the mastery of a crisis situation.

REFERENCES


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