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# HOW CAN (SERIOUS) GAMING HELP TO TRACE AND IMPROVE SNOW AVALANCHE EXPERTISE PROCESS? AN INNOVATIVE METHODOLOGY AND APPLICATION TO ROADS RISK MANAGEMENT

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**ABSTRACT:** Management of mountain roads exposed to snow avalanches involves several actors local who have often to take difficult and quick decisions under social, political, economic pressures in a context of imperfect (lacking, incomplete, conflicting or uncertain) information. An innovative serious gaming concept is proposed to both aid, improve and trace decision processes considering influence of information quality on decisions.

**KEYWORDS:** Snow avalanche, roads, risk management, crisis, decision-making, serious gaming, expertise, information quality, traceability.

## 1. INTRODUCTION

All mountain natural risks management involves several actors such as local authorities representatives, technicians, infrastructures managers, security and safety operators, phenomenon's experts who have often to take difficult and quick decisions under social, political, economic pressures in a context of imperfect (lacking, incomplete, conflicting or uncertain) information. Several critical situations have occurred during Winter 2017-2018 in Western Europe with several transport networks touched by snow avalanches events (see Figure 1). Managing critical infrastructures such as roads exposed to snow avalanches is a typical example of those tricky decision contexts. Transport infrastructures are essential for economic, social and safety reasons and closing a road is never an easy decision due to consequences it may induce. If you were in this situation, which decision would you take? How would you describe your reasoning process leading to that decision? How could you transmit, share your knowledge to others less experienced colleagues or non-specialists involved in decision-making? How would you assess and consider information quality and its influence

on your decision? All those questions relate to assessment of information traceability within expertise and decision-processes which are of higher interest for experts and decision-makers.



Figure 1: Removing snow on road RD 902 after exceptional snow avalanche occurred on 8th January 2018, Bérion, Savoie, France (courtesy of A. Duclos)

To aid decision-making and capitalize information, specific design methodologies and techniques are missing to design information systems able to capture and represent linkages (traceability). This paper describes an innovative serious gaming

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process proposed both to aid, improve and trace decision processes considering influence of information quality on decisions.

## 2. EXPERTISE & DECISIONS' TRACEABILITY NEEDS

Every mountain professional, local authority's or State's representative, technical staff, infrastructure dealing with snow avalanche has sooner or later to take decisions to manage associated risks. Those decisions depend on available information and are often the results either of a group decision or an incremental, sequential process: results from one source is used by another to produce another result which will be a partial intermediate result but also an input for another process (see Figure 3). In this process, in real life situations, experts advise infrastructures managers. All decision-makers may not have the same technical, administrative backgrounds, objectives and constraints. Understanding the global process, nature and possible imperfection of available information is essential for all those steps to understand each other but also to improve global assessment.

However, describing a decision process is not an easy job. Analyzing, understanding why and how a decision is taken or justified is a tricky point since rationality and intuition may act in contradicting ways during decision-making processes, see Kahneman, 2011.

### 2.1 Expert assessment process and risk management decision

Managing risks and critical infrastructures such as road networks requires addressing classical steps ranging from prevention to crisis management and recovery (see Figure 2).

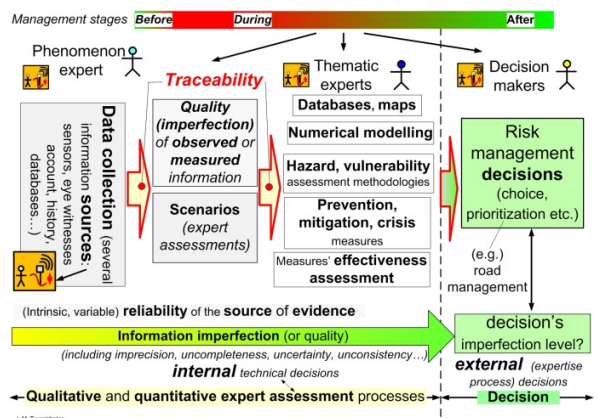


Figure 2: Concept of traceability, adapted from Tacnet et al. (2014).

Decisions are based on a combination of technical steps using available but often imperfect information provided by more or less reliable sources (sensors, historical records, eye witness accounts, models...). Explicit description of this information chain may be complex and partially done when several actors are involved (see Figure 2). For snow avalanches, despite of recent advances in science, expertise is always required in addition to any others tools or models, see Duclos et al. 2017.

### 2.2 Decision processes traceability

Traceability is therefore essential to enhance an effective communication between actors involved in decision processes and to explain and justify a posteriori reasons for choices.

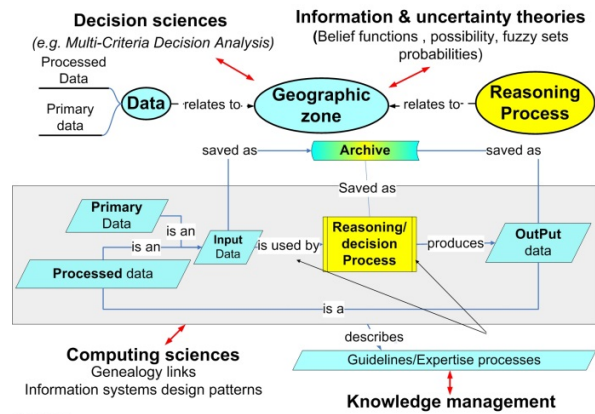


Figure 3: Pluridisciplinarity is needed to represent a reasoning process, setting up and showing links between information, see Tacnet et al. (2014).

From a practical point of view, traceability corresponds to the description of links existing between an output, a result (e.g. a decision) and input data which have been used to reach it (see Figure 3) with application in information systems.

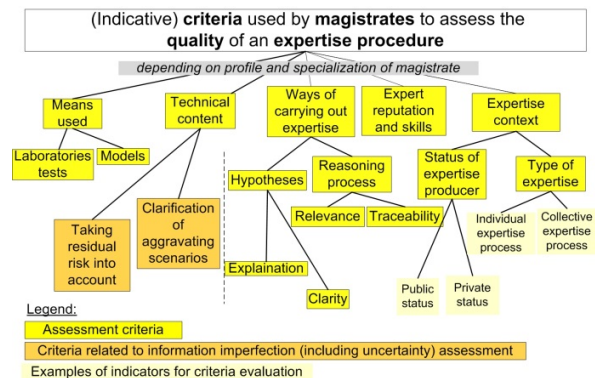


Figure 4: (Indicative) criteria used by magistrates to assess the quality of an expertise procedure.

Figure 4: Traceability, explanation and clarity of expertise processes are expected by judges, Tacnet et al. (2014).

This traceability is already part of expertise standards requirements (e.g. NF X 50-110, AFNOR 2003) and can appear as a key factor in some dramatic cases where responsibilities can be searched in legal and judicial proceedings (see Figure 4).

### 3. DEVELOPMENT: FROM EXPERT ASSESSMENT TO SERIOUS-GAME DESIGN

A serious game is a way to present a process in an alternative way to classical education and learning devices, see Djaouti et al., 2011. To compensate existing shortcomings and control all decision's features, the idea has raised to design a serious-game where players would be an expert, a road manager, a mayor...involved in a risk management decision process: as a player, you are indeed facing a heavy snow scenario with high traffic expected in a critical period and you have to decide whether you should or should not close the road because of snow avalanches risk (see Figure 8).

#### 3.1 Describing decisions contexts

In real life, getting accurate and comprehensive event management feedback remains tricky: getting all information needed especially actual nature, quality and schedule of incoming information often remains difficult.

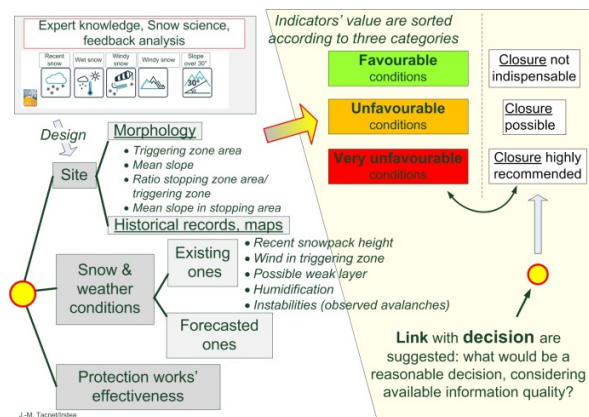


Figure 5: Expert knowledge is derived into criteria, indicators with values range corresponding to decision/assessment classes.

To describe real cases, a close collaboration with experts involved in snow science, education and

winter infrastructures management has allowed to identify the main situations' features, to describe scenarios and then design a simplified assessment framework. Well known and widely used snow and avalanche science or knowledge is the basis to choose main criteria, their relative importance, the indicators to measure them and, finally, the values range to sort different situations into possible decisions (see Figure 5). Information is more detailed depending on versions of the game, planned to exist from "intermediate" to "advanced" levels.

#### 3.2 Gaming rules and support tools

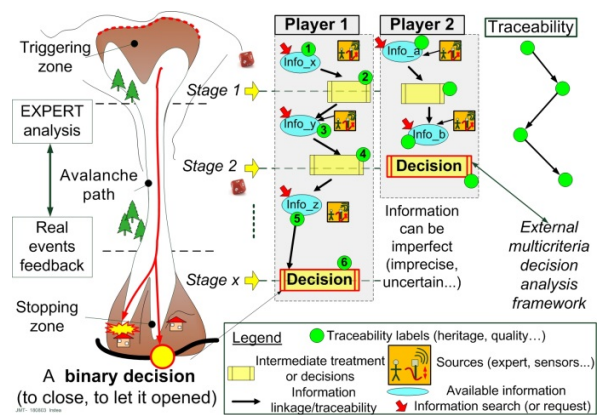


Figure 6: The game is a traceability tool within the expert assessment process.

The principle of the game is derived from an existing application for maritime security (NATO/CRME) proposed by Jousset and Locke, 2015. This concept has been tailored to a simplified version of a snow avalanche expertise. It consists in asking a player (representing a decision-maker) to take a decision on the basis of information, possibly imperfect, provided in an incremental way during the game (see Figure 6). Player gets information he asks for but the quality of information may be poor (e.g.: he asks for snow height from a sensor but the sensor may be out of order, an observation may have been done under bad visibility conditions...). As the goal of the game is also to educate, the player gets, before playing, global explanations depending on its professional skills. Two profiles will exist (intermediate and advanced skills corresponding respectively to a non-specialist of snow avalanches and a kind of expert). Until now, only the intermediate level of game has been designed. Principle of the game is described as follows. The game master first describes the decision context and the principle of the game: "You are either a group of persons or a

single actor facing a forecasted heavy snow event and having to take a decision whether the road should be closed or not". Three main situations are identified (Closure not indispensable, Closure possible, Closure highly recommended) (see Figure 5). This road is a strategic communication axis and the period is highly critical (meaning closure may have severe economic, security consequences...). At each stage of the game, the player has access to different kinds of information related to main criteria used to assess snow avalanche triggering conditions (see Figure 5). He chooses information he wants to get (morphology, historical records, snow conditions...) and then rolls a dice which will decide the quality of information he will get. The master of the game gives information while the player does not know exactly the type of information imperfection he will have to cope with. Once the player has got this piece of information, he is asked to give a confidence level to the three decisions hypothesis (HD1, HD2, HD3) (see Figure 8). He can then decide or continue playing.



Figure 7: Gaming material consists in cards, knowledge factsheets.

While you play, external events happen randomly (e.g. avalanche has triggered in a near valley...). At the end, you have to justify your decision, as if you were in a real situation facing (e.g.) State, Local communities or Economic actors representatives. All information got by the player is carefully registered. The way information is chosen and the order of choice give precious feedbacks about the reasoning processes defining some key users profiles. In practice, a game toolkit has been designed using cards, table layout, an hourglass, multi-faced dices to decide about information quality at each stage of the process.

### 3.3 An indicative validation process

Without any control, each player can decide anything (to close, not to close) at any moment of the game being possibly inconsistent according to available information: it is therefore interesting to be able to compare decisions which has been taken with a kind of most reasonable decision based on available information quality and sources reliability.

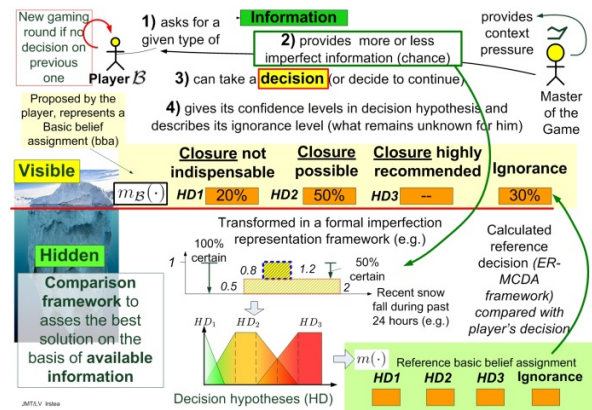


Figure 8: A validation process using multicriteria decision analysis and information imperfection assessment

An hidden part of the game consists therefore in designing and using a multi-criteria decision-making framework to identify what should be done. We are using recent multi-criteria decision making methods which are able to consider information imperfection and sources reliability using uncertainty theories such as fuzzy sets, possibility, belief function theories see Tacnet et al., (2017), Smarandache et al. (2004-2015). In real applications, information quantity may be quite substantial, making the use of information systems mandatory to handle amount of data, represent and store traceability features: specific design patterns are needed and under development.

## 4. CONCLUSIONS

Traceability of decisions processes is of higher interest in risk management processes. We have designed an original methodology and tool combining a serious gaming framework, a formal traceability process to be implemented in information systems and also a proposal of a validation framework. Such serious-gaming is indeed both an innovative and a very effective way to educate but also to analyze and possibly improve expertise and decision processes. It is also a great support

for research on decision-making, information traceability in expertise and decision processes.

This **serious game** is an **innovative framework** and tool since: **1)** it proposes a new alternative tool to classical methods to describe and formalize decision processes to manage roads exposed to snow avalanches; **2)** it offers an original and unique way for cross-exchange between both actors but also methods and disciplines. This pluridisciplinarity is an added value for both of decision' actors; **3)** it can be used either to illustrate concepts, to educate, improve decision processes through enhanced communication and finally **4)** it can be considered as a decision-lab where all information is strictly controlled, monitored and traced in relation with decisions taken. It therefore offers a unique framework to analyze the influence of information quality on decision and also to validate research developments in the field of information imperfection management.

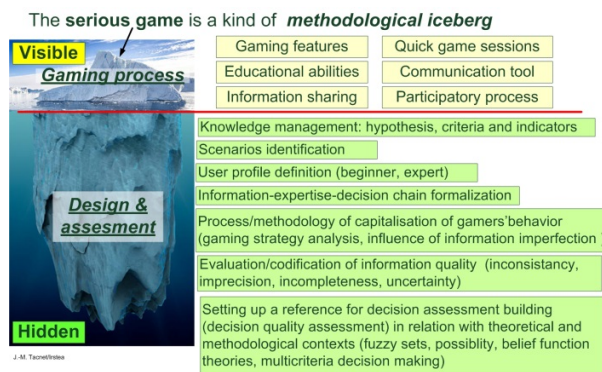


Figure 9: Design process and assessment methodologies of the serious game are not visible.

Behind the visible part of the game, several advanced techniques and methods are indeed combined (in an hidden way for the user) to trace decision processes and steps (see Figure 9), to assess decision relevance and propose an innovative validation process using conceptual software modelling, advanced multi-criteria decision-making, uncertainty theories (Probability but also Fuzzy sets, Possibility, Evidence theories). In practice, development of such a game is not an obvious and straightforward process first because it has still to be somewhere fun despite of risk context application. Some issues and critical watch-points remain. First, risk management is a sensitive domain. Such a game should be strictly considered as an educational and capitalization tool to formalize knowledge. This tool is neither an expert system nor a unique indisputable and absolute theoretical decision-making system. By con-

trast, it should be considered as a way to make explicit and understandable reasoning steps, constraints, doubts within the expertise process. Secondly, development requires a close, complementary collaboration between experts, decision-aiding analysts and targeted users. Present version of the game has been focused on the case of critical networks infrastructures with a first simplified version. Extensions are of course and under consideration, for example for risk zoning maps design. It will also be used as a validation tool of software design patterns specifically developed to consider traceability and information imperfection in information systems used for expertise: an on-going PhD deals with decision-making and information conceptual modelling on this topic. It will also support developments about decision support in context of imperfect information.

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