FLOODSTAND-deliverable:

Standard for decision making in crises - loss function

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Abstract:

A review of decision making based on quantitative principles are presented and an heuristic set of loss function is proposed. The selection of the format to be used for decision making was made based on an integrated standard in deliverable D6.2.

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Executive Summary

A review of decision making based on quantitative principles are presented.

A general consensus in the literature of the mental and sense making modelling is that typical reasoning based on cognition is relatively reliable for basing decisions under previously experienced, routine, cognitively manageable, clearly structured and low stress conditions. As conditions move progressively towards the characteristics of extreme crises, then the reliability of these frameworks as a basis for intuition degrades. Therefore, decision making to mitigate crises seems to be particularly subjected to uncertainty of not only the inherent situational characteristics, but also the whole process of its handling, from human effects of the crew, to the availability of the necessary hardware in case scenario such as collision or grounding occurred.

Therefore, decision making standard must follow formalism capable of addressing the expected complexity of the uncertainties involved.

The discipline of decision theory offers two broad models to tackle the issue, the concept of expected disutility, and the prospect theory. Both have been considered as the means for rationalising choice under uncertainty.

Whilst these models offer rational formalism, both suffer from permitting subjective assignments of parameters whilst making decisions.

To apply them to crises handling it is proposed to assign parameters as part of regulatory decision making, so that real life crises can be followed in uniform fashion. Loss function and likelihood function are to fulfil these roles.

The loss function is shown in the literature to be of fairly uniform format, referred to as alfa-models, with a set of fixed parameters purporting to model societal aversion to consequences of given magnitude. Whilst the range is fairly confined, it is still considerable in terms of the quantitative impact on the calculated values of risk. Moreover, there does not seem to be clear consensus on appropriateness of one model over another, which would have been justified through clearly quantifiable psychometric measures of societal aversion.

Therefore, it is proposed that to reflect the observed tendencies of aversions, the following heuristic set of loss functions is considered for decision making standard.

$$N^{\alpha} \text{ where } \alpha = 0.5,1,2,3 \text{ and N is number of fatalities}$$

The selection of the format to be used for decision making is made based on an integrated standard reported in the deliverable D6.2.

Table of content

1 Introduction

Improving safety and security of surface transport may be achieved by developing technologies and intelligent systems, including monitoring systems, rescue procedures, and crisis management, to protect vulnerable persons.

One of key elements of providing with such intelligent systems is development and deployment of a crisp merit function to form basis of a decision support.

When decisions must be made during an evolving crisis, the function of decision support becomes the last option for its effective mitigation that is available to the crew.

In case of passenger ships, loss of life is the consequence that would be considered in making the final decision of ship abandonment, and at present the decision is discretionary and it rests with the captain (or on-shore command officer).

Whilst it seems rational that the responsibility for the persons onboard a ship in crises must remain with the master, it would seem prudent that decisions made, such as on ship abandoning, are reflective of the state of the art scientific understanding, possibly expressed as a clear and agreed internationally criterion. This would help the crew to make more efficient decisions, assure a degree of uniformity in handling serious crises situations, and more importantly, it would transfer some of the burden of responsibility for outcomes of the crises to the whole professional community or indeed, the society, which in the end may help the decisions to be less stressful and thus more rational.

This report summarizes a proposal on elements of such specific criteria for decision-making or indeed, for the process of handling crises involving many persons.

2 Objectives

This task sets to devise a basis, a standard, for decisions on abandonment, so that either the crew or the on-shore team advises accordingly to rigorous criteria accommodating for all information that is relevant to such decision making at every instant of time, as well as for all the uncertainties associated with eventually committing to this decision.

It was proposed to form such a standard on the basis of concept of risk, and two its elements, a loss function $loss(N)$ and $p_{N|i}(N|decision_i)$ were set to be developed.

The loss function must reflect in a balanced manner the societal concerns pertinent to a “large” loss. The $p_{N|i}(N|decision_i)$ must reflect the state of stability, evacuation and rescue process as well as the associated uncertainty.

This report outlines the proposed set of the loss function.

3 Approach adopted

The approach evolved somewhat during developments in the project from the initial outlines.

After basic literature review relating to the decision making and an initial prototype modelling, majority of the effort was spent on examining the decision function in an integrated format, whereby all elements of ship survivability as well as the whole process of evacuation and abandonment were examined in detail.

For the purpose of formal reporting, this report summarises the loss function. The selection and the reasoning that led to putting forward of the ultimate proposal is presented in deliverable D6.2.

4 Frameworks of decision making

4.1 Cognitive decision making

Bad decisions can exacerbate crises and good decision making can help to steer a situation away from, or out of crisis, [7]. Most people may consider themselves good decision makers, reflective when needed, intuitive and decisive when that is required, prepared to consider alternative perspectives and aware of the mistakes that others have made in the past. The reality however may be less forgiving, especially with respect to handling crises situations.

Crises abound and few institutions and organisations seem immune to them. Crises defy precise characterization, but typically they are unexpected, abnormal and novel, volatile, inherently unpredictable and giving rise to conflict between objectives. Impacts may be interdependent and non-obvious, and participants will be under time pressure and other forms of psychological stress in responding to them.

A general conclusion of the mental models and sense making literature is that typical reasoning based on cognition is relatively reliable for basing decisions under previously experienced, routine, cognitively manageable, clearly structured and low stress conditions. As conditions move progressively towards the characteristics of extreme crises, then the reliability of these frameworks as a basis for intuition degrades.

As such, decision making to mitigate crises seems to be particularly subjected to uncertainty of not only the inherent situational characteristics, but also the whole process of its handling, from human effects of the crew, to the availability of the necessary hardware in case scenario such as collision or grounding occurred.

Practically, crises will not typically allow decision makers to ‘wait and see’ until critical uncertainties are (certainly) resolved, and decisions will often need to be made when events, their implications and future developments are unclear.

For these reasons the process of decision involving serious flooding crises should be formalised, as it does not seem rational that the weight of responsibility for (often) so many is in the hands of so few and given the degree of uncertainties involved, as described in WP4 of this project. For these reasons also the formalism adopted must reflect the key problem of handling crises, namely the presence of uncertainty.

Choice under uncertainty represents the heart of decision theory, and the concept of expected utility (or disutility) has been considered for centuries as the means for rationalising such choice.

The idea of expected utility is that, when faced with a number of actions, each of which could give rise to more than one possible outcome for which different probabilities would be assigned, the rational procedure is to identify all possible outcomes, determine their utility (positive or negative) and the probabilities that will result from each course of action, and multiply the two to give an expected utility (or disutility). The action to be chosen should be the one that gives rise to the highest (lowest) total expected utility.

However, Tversky and Kahneman, [8], have demonstrated in numerous highly controlled experiments that most people systematically violate all of the basic axioms of subjective expected utility theory in their actual decision making behaviour at least some of the time.

These findings run contrary to the normative implications inherent within classical subjective expected utility theories. In response to these findings, they provided an alternative empirically supported theory of choice, one that accurately describes how people actually go about making their decisions. This model is called prospect theory.

Prospect theory predicts that individuals tend to be risk averse in a domain of gains, or when things are going well, and relatively risk seeking in a domain of losses, as when a leader is in the midst of a crisis.

In making a decision, a decision maker multiplies the value of each outcome by its decision weight, just as expected utility maximizers multiply utility by subjective probability, [8]. However, decision weights in prospect theory differ from those in subjective expected utility theory, because decision weights do not obey any of the rational choice probability maxims.

Decision weights do not serve solely as measures of the perceived likelihood of an outcome, as probability does in subjective expected utility theory. Rather, decision weights represent an empirically derived assessment of how people actually arrive at their sense of likelihood, rather than a normative standard about how they should derive probability, as subjective expected utility theory advocates.

As can be seen, either of these basic concepts of decision making underlines <u>subjectivity of decision maker</u> in rationalising choices.

This is the reason for the proposal of an alternative standard for handling crises involving ship flooding, devoid of subjective assessment.

Neither the probability should remain subjective in expected utility nor the weights should reflect the inefficiencies of human decision making when for instance under stress in prospect theory.

4.2 Risk aversion

The compromise solution is proposed to adopt the format of the expected disutility, shown as expression (1), however, with none of its elements allowed to be based on subjective influence of the decision maker.

Instead, all its parts should be derived through scientific reasoning, such as presented in WP4, WP5 and here, and remain constant so to ensure uniformity of decisions as well as their adherence to wider societal expectations.

$$E(loss|decision_i) = \sum_j loss(j) \cdot p_{N|i}(j|decision_i) \quad (1)$$

For $j = 1 \ldots N_{max}$ and where N_{max} is total number of persons onboard.

The equation (1) is the generalised quantitative measure of risk defined as a mathematical function of the probability of an event and the consequences of that event, e.g. [16].

As just mentioned, the probability assignment must reflect the state of knowledge of the processes involved in flooding situation, that is likelihood of ship capsize within foreseeable future, as well as likelihood of fatalities during abandonment and rescue process. The important aspect is to remove crew subjectivity as far as practicable from making projections, as these can lead to either inefficient or irrational decisions when made in crises.

A proposal on such a process of probability assignment is subject of task 6.2.

The format of the consequence function $loss(j)$ is proposed to reflect wider perceptions of risk to life, and especially risk involving multiple fatalities, and often considered as "societal" risk.

Decisions on risk tolerability are typically made on the basis of considerations of cost-benefit analysis (CBA) of given activity or similar, e.g. [12], [13], [14], [15], [16], [17].

However, the CBA is not always applicable, as it is not possible either to identify in advance or to value all the major consequences of accidents. The most common such situations are in the appraisal of the risk of major accidents, because major accidents may have repercussions that go much wider than their direct effects on people and property.

Some examples of accidents that can have wide repercussions are major public transport accidents, such as air crashes: these can alter the perceptions of risk by passengers and thus affect demand, with widespread economic consequences, which cannot be quantified easily. Other examples are major industrial accidents, which may have far-reaching political and regulatory consequences.

In such situation, a workable alternative to CBA is to adopt direct criteria based on the absolute values of societal risk, such as given by (1).

Other methods of expressing risk, such as $F_N(N)$ curves, are not used in this work, as it is the objective to provide the crew with criterion not requiring any complex interpretations, and therefore aggregate, or descriptive, statistics such as (1) seem to be the only alternative to avert ambiguity. However, aversion to risk, especially if the consequence can reach catastrophic dimensions, must be expressed by such aggregate numerals.

Several efforts in the past have been reported, on incorporating risk aversion into risk integral (1) through some formats of the function $loss(j)$, with an extensive overview given in [16].

Some studies, [22] argue that risk aversion built into (1) is not representative of its true sources, in particular dread of unbounded consequence and unknown nature of the consequence, which seem to contribute to societal risk aversion much more than so-referred to alfa models of loss function permit.

Whilst such criticism seem supported by systematic analyses in [22], it is proposed here that the nature of risk in case of flooding crises is not unbounded (the maximum loss of life is known), as well as it's nature is well understood by the public unlike cases of nuclear disasters, which consequences can be distorted by images of nuclear weapons, adding to dread and thus aversion.

Moreover, the anticipated application to a standard for crises management on relative basis permits some flexibility in risk modelling itself, since decision ranking will be based on the same format of risk, and therefore any conceptual error in representing societal concerns will impact decisions in similar fashion.

Therefore, it seems that approximating loss function by means of the "alfa" model is adequate for the purposes of this project. The question remaining is on the range of the parameters, which seems widely studied in the literature.

The British Health and Safety Executive, [21], constructed a weighted risk integral as given by equation (2), with aversion to accidents with many fatalities represented by a coefficient $\alpha = 1.4$.

$$RI_{COMAH} = \int_0^\infty x^\alpha \cdot f_N(x) \cdot dx \qquad (2)$$

The loss function can be thus be expressed as follows:

$$loss(j) = j^\alpha \text{, where } \alpha = 1.4 \qquad (3)$$

Similar measure was proposed by [19], with the parameter $\alpha = 1$ to $\alpha = 2$, or as summarised in [22] by Griesmeyer and Okrent [23], with tentative model with $\alpha = 1.2$, Wilson [24] $\alpha = 2$, or Ferreira and Slesin [25] whom proposed $\alpha = 3$ to represent the philosophy that "the value of each individual life lost in a single accident is greater than the one before", and based it on the relationship between number of deaths due to fires, natural disasters, mining or transport accidents, and frequency of their occurrence.

An alternative presented in [16], [15], [18] is derived as the perceived collective risk R_p, given by (4), as a measure for societal risk, where $\phi(x) = \sqrt{0.1x}$ is the risk aversion function.

$$R_p = \int_0^\infty x \cdot \phi(x) \cdot f_N(x) \cdot dx \tag{4}$$

This can indicate the loss function of the following format:

$$loss(j) = 0.316 \cdot j^\alpha \text{, where } \alpha = 1.5 \tag{5}$$

Similar function (6) was reported to be proposed by [20], with α between 1 and 2 and some constant C.

$$\int x^\alpha \cdot C(x) \cdot f_N(x) \cdot dx \tag{6}$$

It appears that the general consideration of aversion by means of some format of the loss function is represented by the above outlined concepts, which attempt to reflect the recognised non-linear aspect of human reaction to catastrophes, e.g. [9], whereby the society appears more willing to accept a technology that will result in a number of separate fatalities than one which results in a large number of fatalities from a single event, even though the totals over time may be the same.

This background review is considered sufficient to the proposal of a loss function.

4.3 The loss function

The concepts documented in the literature, as summarised above, are shown in the following Figure 1.

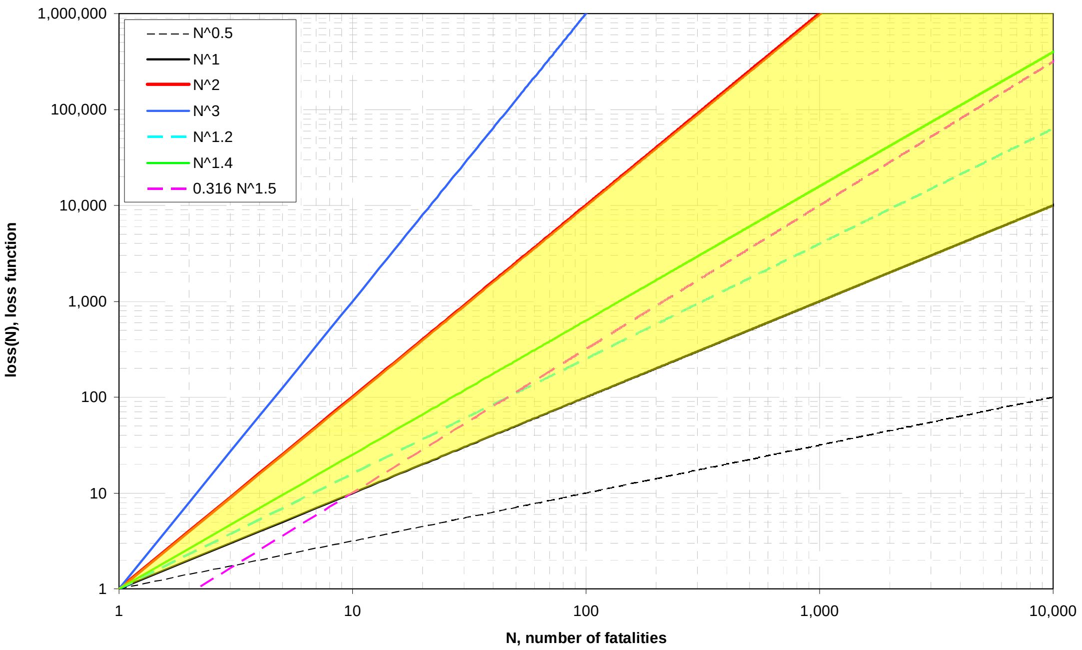

Figure 1 Proposed range of loss functions. The literature indicates the region marked in “yellow” as the most often chosen risk aversion function.

Whilst the range discussed above is fairly confined, it is still considerable in terms the quantitative impact on the calculated values of risk. Moreover there does not seem to be clear consensus on appropriateness of one model over another, which would have been justified through clearly quantifiable psychometric measure of societal aversion.

Therefore, it is proposed that to reflect the observed tendencies of aversions, as summarised above, the following heuristic set (7) of loss functions is considered for decision making standard.

$$\begin{aligned} Loss(j) &= j^{0.5} \\ Loss(j) &= j^{1} \\ Loss(j) &= j^{2} \\ Loss(j) &= j^{3} \end{aligned} \qquad (7)$$

Since the specifics of the task of proposing of an integrated standard, allow inherently for risk-comparative format, rather than an absolute one, such set can form basis for sensitivity studies for the recommendation of the standard.

Such sensitivity study requires examination of the whole concept, and therefore the study is documented in D6.2 of this project.

5 Conclusions

A review of quantitative methods for rationalising decision making was performed.

An heuristic set of sensible loss functions was put forward.

The selection process proved to be unnecessary due to the nature of the proposed integrated standard for decision making. The details were explained in deliverable D6.2.

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