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Citizens and governance in a knowledge-based society

COORDINATION ACTION



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Comparison of Approaches to Risk Governance

WP1 – Risk-Informed Decision Making (RIDM)

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1. INTRODUCTION

We are presently living in a world characterised by an increased complexity of fast-pace, interconnected and interdependent systems, resulting in the need for society to better manage the multi-dimensional risks (social, environmental, cultural, economic, political, etc.) related to such systems. This in turn led to the increased development of RISK MANAGEMENT, which is a multi-discipline that prospered in importance and gained momentum in the 20th Century and is establishing a crucial role in the 21st Century. Linked to risk management is risk governance. According to the International Council of Risk Governance (IRGC): *“Governance refers to the actions, processes, traditions and institutions by which authority is exercised and decisions are taken and implemented. Risk governance applies the principles of good governance to the identification, assessment, management and communication of risks. It incorporates such criteria as accountability, participation and transparency within the procedures and structures by which risk-related decisions are made and implemented.”*¹ The IRGC goes on to explain that risk governance is of particular importance in, but not restricted to, situations where there is no single authority to take a binding risk management decision but where instead the nature of the risk requires the collaboration and co-ordination between a range of different stakeholders [1].

There is an increasing need for the use of integrative approaches to the governance of risk. In this light there are many and how risk-informed decision-making; a precautionary approach; and a deliberative approach are all important aspects of risk governance.

The main steps of the risk governance have to give answers to issues as follows:

- Identify risk, which is of concern.
- Plan the process of risk evaluation and management.
- Define the scope, the parts involved in the process, the objectives of the evaluations and actions involved by them.
- Define the uncertainty and boundaries in the decision process framework for each of the activities.
- Perform risk analysis.
- Define the risk mitigation actions based on the risk analyses results.

Three approaches to support risk governance are evaluated in this report, with a more detailed focus in RIDM:

1. Risk informed decision making (RIDM)
2. Precaution and risk reduction principle (PRECP)
3. Risk deliberation (DELIB)

There are some general features to those approaches as follows:

- Risk informed decision making is more based on quantitative assessments than the other two.

¹ <http://www.irgc.org/What-is-risk-governance.html>

- The precaution and risk reduction approaches involve both qualitative principles and more traditional risk assessment.
- The deliberative approach means that more of the risk governance philosophy is given to lay people taking their concerns and values more into account.

Suggested general assumptions to be considered in the report and conclusions - The generic features of the approaches required to support risk governance (RG) indicate the expected complementarity of theDocview9

ir application

* The present document will aim to show some insights on how the **RIDM** could fulfil its goals to support **RG**. The presentation is done from the perspective given by the complementarity principle of methods supporting **RG**.

* For this goal this document includes presentation of the general basis for **RIDM**, possible applicable method for **RIDM** and specific evaluation samples are also included, as well as references and short insights and comparisons with the other applicable approaches (e.g. **PRECP** and **DELIB**)

* It will be considered that the **RG** context is set up by the facts provided by the experts, stakeholders pressures groups and/or extensive media coverage.

1.1 RIDM – SOME BASIC ISSUES AND GENERIC ASPECTS

RIDM is one possible approach to be integrated in the models related to risk governance.

There is a connection between various notions as complex systems, risk and decision making, for which a possible integrative view is proposed below. In short the view tries to underline that the need to manage complex systems leads to the need to manage the risks implied and/or generated by them. Furthermore, their management process needs to be founded on specific tools.

1.1.1 Decision making process

Decision-making (DM) is considered to be a cognitive process leading to the selection of a course of action among variations [2].

Every decision-making process produces a final choice. It can be:

- an action or
- an opinion.

It begins when *we need to do* something but we do not know yet what exactly. Decision-making is therefore considered to be a reasoning process, which can be

- rational or
- irrational,

AND can be based on:

- explicit assumptions or
- tacit assumptions.

A decision process can be represented as in Figure 1

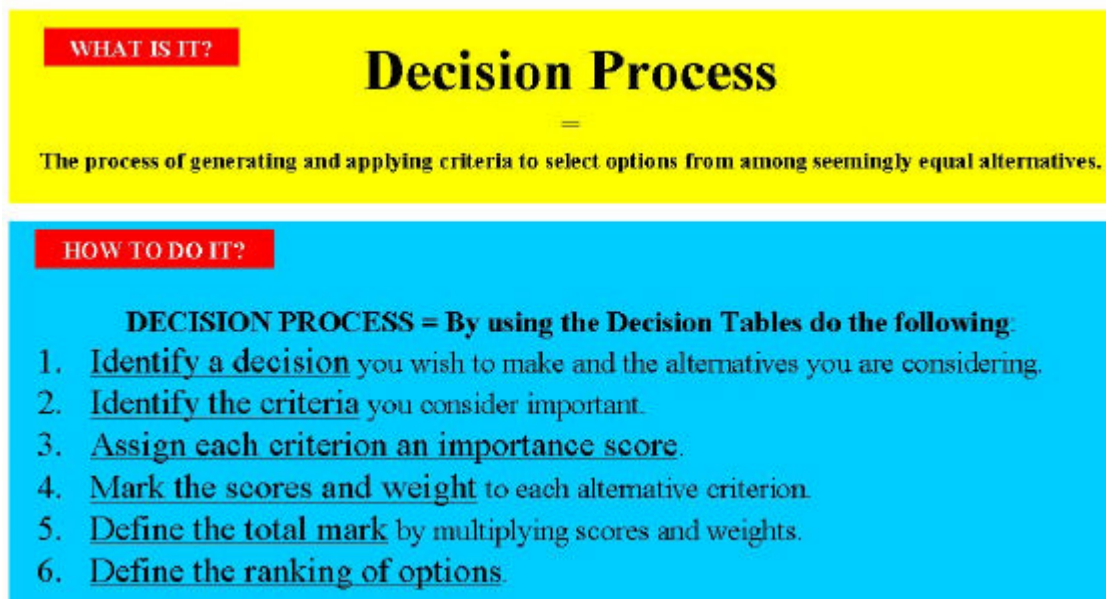


Figure 1. Representation of the Decision Process [3]

Decision process implies the performance of a decision analysis. The term decision analysis was initiated in [4]:

Decision analysis included in this view the following steps:

1. Graphical representation of decision analysis problems commonly use
 - i. influence diagrams and

- ii. decision trees.
- 2. Both of these tools represent the alternatives available to the decision maker, the uncertainty they face and evaluation measures on how well they achieve their objectives in the final outcome.
- 3. Uncertainties are represented through:
 - i. probabilities and
 - ii. probability distributions.
- 4. The decision maker's attitude to risk is represented by:
 - i. utility functions
 - ii. decision is considered by looking for an optimum between conflicting objectives / utility functions
- 5. The evaluation of the utility functions and the calculation of optimum is made by using multi-attribute functions.

1.1.2 Risk and complex systems

Risk is a characteristic of complex systems and it is related to complexity. Complex Systems (CS) have some specific features as represented in table 1 [5,6,7,8,9]

Table 1. Features of Complex Systems (CS)

Complex Systems (CS) are systems with specific features	
1	The system is characterized by the fact that the interrelations between its elements/components create a synergetic effect, which actually makes the system unique. The interactions are of short distance between elements or of long distance (in space and time)
2	The existing relationships in a CS are defined by the existence of feedback loops, which results in a dynamic system structure, with constant nonlinear interfaces.
3	CS are interacting with the environment, being open to the exchange of energy and information.
4	No part of a CS can contain the whole and therefore no part can assure the control of the whole CS. This could lead to specific tools for controlling it, like for instance distributed control, hierarchical control and/or external to the CS unitary control. However
5	CS elements are CS themselves and are highly adaptive, which introduces another difficulty in the choice of the modelling tools.
6	CS have a historical hysteresis characteristic, in the sense that they have a history and that leads to an effect known as "the butterfly effect", i.e. a small change in time and space will impact on the future history of the whole CS or to a completely different component than the one that had the initial change. However, even if the interrelations of the components are nonlinear they comply with the cause and effects law in this specific manner. The concept of linearity and nonlinearity apply to the models defined for CS and it is one of the important modelling issues.
7	CS have boundaries difficult to define, which has a high impact on the content of their models and their own changing dynamics and flexibility.

There is a special category of CS called Complex Apoietic Systems (CAS), having the main features as described in Table 2 [5,6,7,8,9].

A Complex Apoietic Systems (CAS) is defined as being CS subjected to a process called autopoiesis [10]. Autopoiesis means "self-production" (self-creation or production) and expresses a fundamental complementarity between structure and function. An autopoietic machine is a machine organized (defined as a unity) as a network of processes of production (transformation and destruction) of components which:

- through their interactions and transformations continuously regenerate and realize the network of processes (relations) that produced them;

- and constitute it (the machine) as a concrete unity in space in which they (the components) exist by specifying the topological domain of its realization as such a network.

Table 2. The features of Complex Apoietic Systems (CAS)

<i>Complex Apoietic Systems (CAS)</i> <i>were introduced by the works of (Maturana 1980)</i> <i>They have the specific features additionally to the generic CS ones, sometimes refining the generic CS features. CAS are systems, for which an autopoietic mechanism can be defined, leading to the system possibility not only to self regulate, but also to recreate itself, as follows</i>	
1	The system boundaries have to be clearly defined at any moment in time
2	The system has to have components, being themselves CS
3	The cause – effect law interactions have to be operable.
4	The system boundaries have to be self produced by the system, as well as
5	The system components
6	The rest of the components should be also be able for most of them to be self produced by the system

The performance of CAS autopoiesis is done by coevolution. Coevolution is being performed at three levels for each system:

- (Bio) Physical level – at the level of the physical part of the system components and structure
- (Bio) Social level – at the level of the system interface with society and other system defined as environment
- Mythico-social level – at the level of concept, objectives and general philosophical interpretation of the CAS issues

The management of CAS involves the management of risks and decisions based on consideration of risks.

A possible view on risk and CS/ CAS is shown in [5-9], where risk is considered as a specific feature describing CS/CAS.

The first recommendation of issues to be mentioned for the RG and RIDM interface is that:

RIDM could be a preferred approach when the evaluation is aiming at achieving its goals and objectives for various actors and at various levels of the CAS:

- Regulators/decision makers
- industry
- general public

due to the fact that RIDM hierarchical evaluation is totally fit to RG goals and objectives.

RIDM is complying with one of the most important aspects of RG related to the interface on the public issues. Its hierarchical and structured approach assumes by default the fact that the feedback between the three levels is assured by:

- Increasing openness
- Public participation and transparency

RIDM is also capable of managing the main factors preventing the achievement of openness, participation and transparency, which have to be dealt with, i.e.

- Increasing complexity of today's society
- Complexity of decision processes and the
- Complexity of the underlying factual basis

1.1.3 Risk analysis and decision making

RIDM may be performed for systems as defined above using a toolbox of methods as represented in Figure 2.

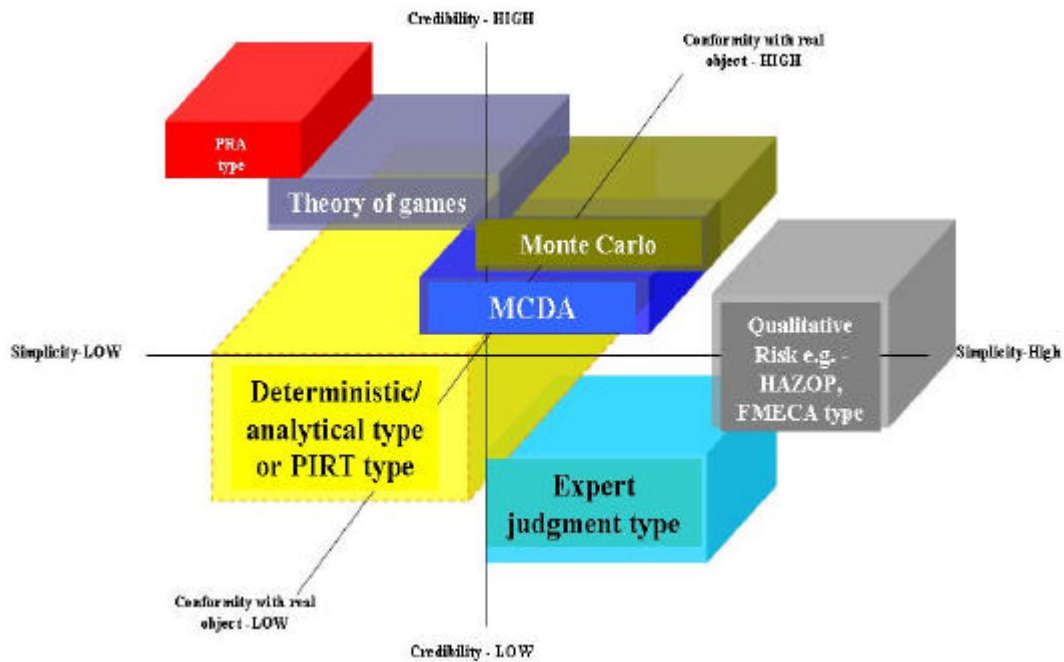


Figure 2. Methods possible to used for RIDM [9]

The methods presented in Figure 2 can be used with strengths and weaknesses for various type of Quantitative Risk analyses (QRA) or Probabilistic Risk Analyses (PRA).

However the present report will focus on the suggestion to use for RIDM specific tasks a specific type of probabilistic approaches, as amended in various works [5,6,7,8,9]. These analyses are used increasingly in the last period of time as a tool to support decision making processes. There are some reasons for which this type of methods can be the preferred ones, of which the most important are as follows:

1. The method may be easily used as a support for decision-making process for CS with interdependencies.
2. The expected answers can be evaluated in both in qualitative and quantitative format and with more details not as a general recommendation / direction only
3. The method is a systematic tool, which is fit for complex systems and with a very well defined and verified procedural set of principles and methods in some complex technical applications
4. The method has the potential to adapt to more tasks than performed now, by including more decision-making areas into the existing framework.
5. The method can be verified and validated and use with high confidence for a given set of boundary conditions and very well defined and known limitations.
6. The apparent complicated aspect can be managed rather easily and actually dependent on the resolution of the model (subsystems, components modules etc).
7. The solutions can be provided in the format from Figure 3, which makes them an important tool for the support of the decision makers. The results are able, as it can be seen from the figure, to support answers and suggestions to the decision

makers on various type of questions, related not only to risk ranking, but also to the credibility of the results and limits of the evaluations.

	CRITERIA/OPTIONS RANKING	Option A	Option B	Option C
1	Criterion 1 = Cost	Medium	High	Medium
2	Criterion 2 = Uncertainty	High	Medium	Low
3	Criterion 3 = Probability	Medium	Low	Low
4	Criterion 4 = Risk	Low	High	High
	TOTAL	Low	High	High

Figure 3. QRA/PRA supported inputs for the decision makers for ranking options

The method is in line with the latest common understanding and reaction in human society to aim at making decisions with low or no risk, which are expected to give answers with less and/or measurable and traceable uncertainty. From his perspective DM process is part of learning about, building and managing CS as models for the real systems existing in the real world, described in a high degree from the decision makers point of view by the risk taken for a given option.

The second recommendation on the Risk-CS-DM interface

* **DM** process, which considers as an information source the aspects related to risk impact of a certain option chosen, is a **RIDM** process.

* Based on the features described above the method **QRA/PRA** can be considered a suitable tool for the evaluation of risks and support to the decision making process **QRA/PRA** is considered a triple S method [5;11], i.e. it is:

Systematic
Structured
Systemic

1.2 PRECP – SOME GENERIC ASPECTS

The precautionary principle is used when there are possible serious risks with large scientific uncertainty [15]. If there are threats of serious or irreversible damage, lack of full scientific certainty would lead to the consideration of highly possibility for high risks due to the need to take cost-effective measures in order to prevent environmental degradation.

This approach usually leads to an opposition to the industry wanting to introduce a new technology from the groups using the precautionary principle as an argument for a moratorium until more is known about uncertain risks.

1.3 DELIB - SOME GENERIC ASPECTS [12]

Motivations for a participatory deliberative approach to issues connected to technology and risk is captured by a the three-fold approach making distinction between

- normative,
- instrumental and
- substantive rationales .

This approach actually means that

- A normative rationale is based on the idea that all citizens have a right to take part in decisions that affect them, and benefits emphasised are empowerment of citizens, equality and social justice. According to this view broader participatory processes are good in themselves.
- An instrumental motivation is based on the idea that the involvement of citizens may lead to increased trust and acceptance, the benefits emphasises are connected to the expected results such as the elimination or mitigation of conflicts and expressed mistrust
- The type of risk issues, which require public deliberation is defined by the rationales for public involvement.

2. METHODOLOGY OF RIDM USED FOR RG

In the context of achieving good risk governance it is important to review that a set of goals, objectives, model and methods are reached by RIDM from risk governance perspective. This part will review systematically all those aspects

2.1 RIDM – SOME ELEMENTS ON ITS HISTORY

Though QRA/PRA have been used extensively in the past, it was usually limited to a variety of applications for some specific areas as for instance in nuclear and with some important modifications in aerospace and chemical industry.

The evaluation of the experience of the use of QRA/PRA indicates on the strengths and limits of the method.

From this perspective of applicability of the methods if we use for the evaluation a space of two features for the CS/CAS analyzed (credibility in assumed conservatism and credibility in uncertainty of the results), then the existing tools, which are split into deterministic and probabilistic categories, can be considered suitable for some specific areas. In this case the existing experience in some areas of CS like for instance in the nuclear field leads to the picture illustrated in Figure 4 [7]. These results are in line with the summary of the RIDM issues in the nuclear field as described in [11].

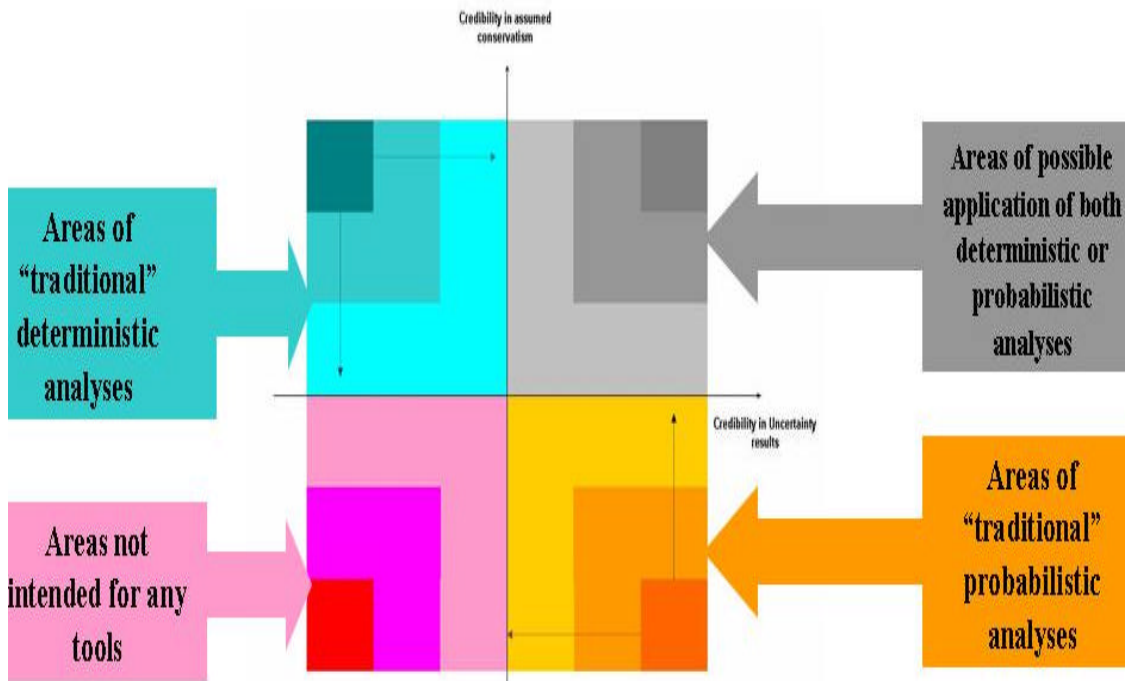


Figure 4. Areas of applicability of deterministic vs. probabilistic analyses

The results of QRA/PRA are then used to support decision makers to evaluate which is the best option to choose from a set of various options possible. QRA/PRA with special modules added for the interface with the decision makers allows also the consideration of the uncertainties and assumptions of each of the options.

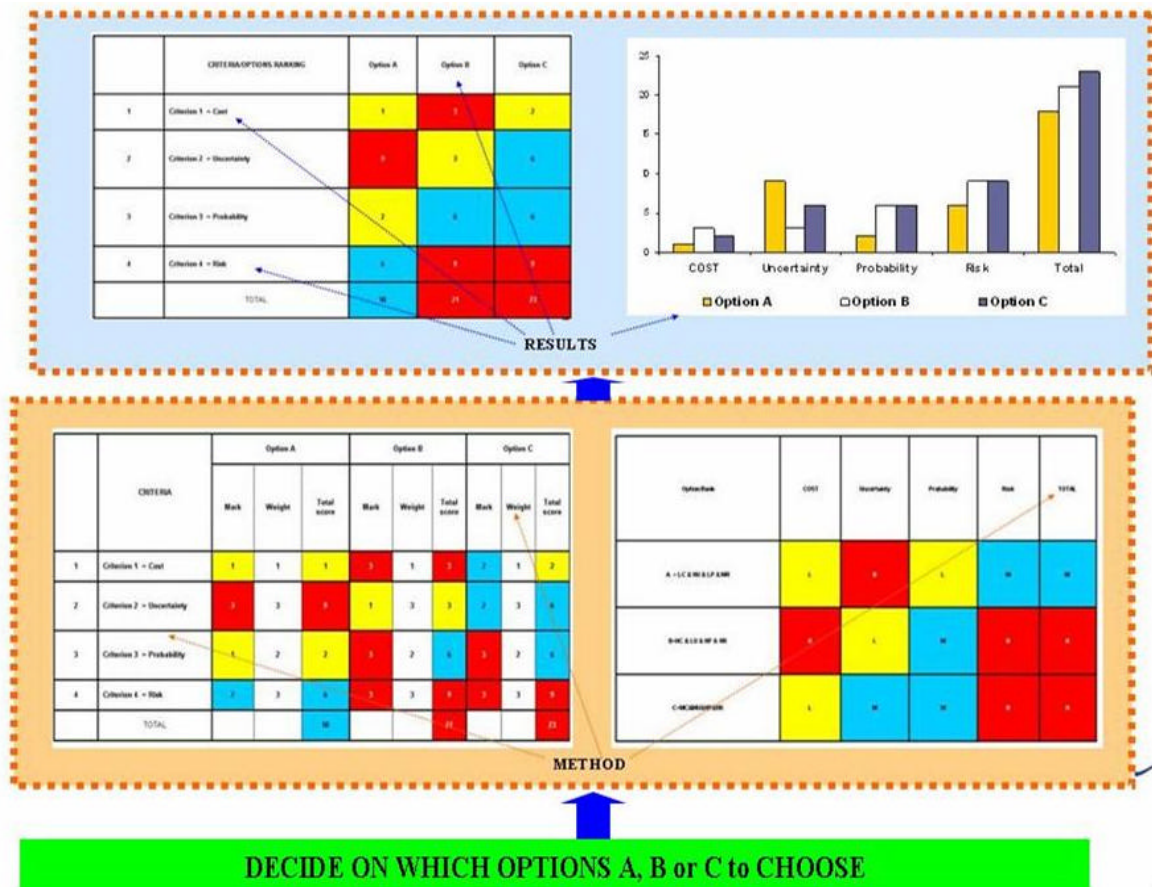


Figure 5. The use of QRA / PRA in the DM process

The process of the interface between the QRA/PRA results after being prepared for the decision making process and the DM process itself then are as represented in Figure 5

The third recommendation on the use of QRA/PRA is:

The use of various tools of QRA/PRA type, which are amended for the interface with DM process is considered highly desirable from the perspective of having a set of tools and results presented with the consideration of their uncertainty (credibility) and a clear traceable and easy to modify list of assumptions.

2.2 RIDM – SOME IMPORTANT METHODOLOGICAL DETAILS

2.2.1 RIDM and Risk Governance (RG) goals and objectives

RG is related to hierarchical structured complex systems, which is the model type used for RIDM models. CAS can be represented like a hierarchical system on three level [13]

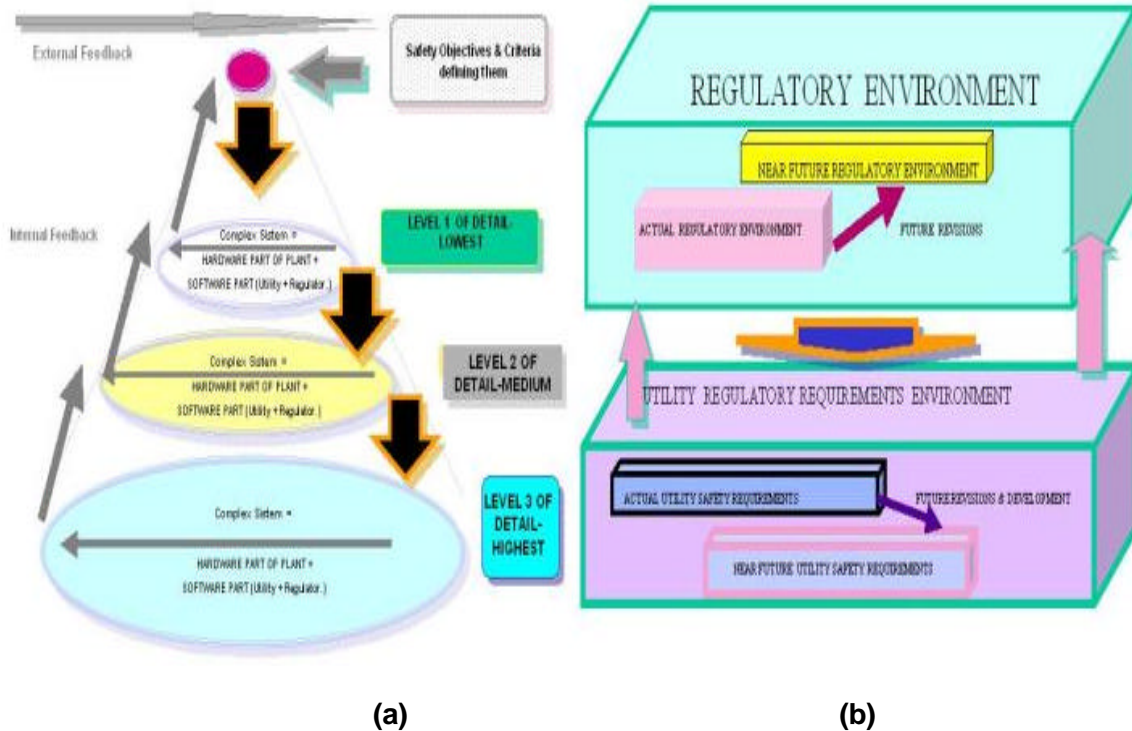


Figure 6. Example of a structure of a CAS model

The model of such a CAS is a hierarchical system. The use of risk like models and methods is based on the existing theories of the complex infrastructures, integrating many diverse aspects, like safety and security. In addition security of supply could be also added as a new supplementary objective function using similar models and methods, provided that the risk aspects are of interest for the objectives of such CAS.

From this perspective CAS can be considered as a three level system, for which the risk is the norm of the departure from optimum and the levels are related to three diverse "actors" united by the whole process:

- Regulators
- Public
- Industry.

In general it can be considered that a CAS model implies the building a sigma algebra for a risk model defined by the components and relationships between the components

of that CAS [5;6;7;8;9] In this case for this structure a norm may be defined, and the norm used is usually called risk.

This approach allows to model various type of interfaces and elements (technical, economical and sociopolitical) On the other side the model is developed on levels and it is expected that the optimum on risk norm for the whole model is reached in in the best stable solutions when the optimum is reached at each level. Practically the QRA/PRA adaptation to such an extended approach implies some refined logical connectors between the elements and a fast traceable software to perform the calculations of the possible scenarios [5;6]. The solutions of optimization for objective functions complying with a Pareto type of limit [5;6] is of type A (without considering uncertainty of results) or of type B (by considering the uncertainty results) as represented in Figure 7. For bi dimensional the curves are noted with index 1 and for a three dimensional representation they are noted with index 2.

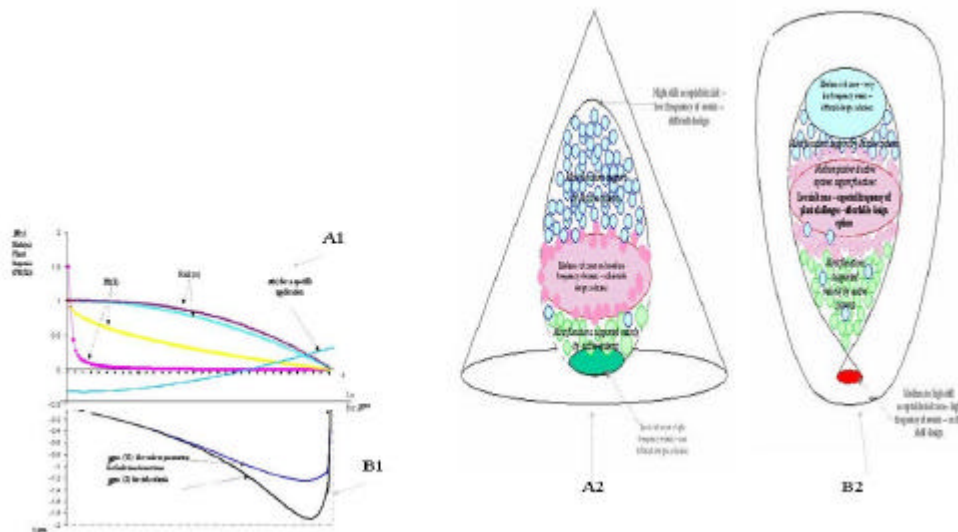


Figure 7. Sample of optimized risk curves for a typical CAS [5;6]

The forth recommendation has to be mentioned also at this step: The use QRA/PRA type, which are amended for the interface with DM process , is considered preferable due to the fact that it is able to assure the following features:

- * The important contribution to the final conclusions of comparing contributors to risk of societal aspects, in all methods used for comparison.
- * The higher contribution of both security type of challenges (with and without barriers designed) by comparison with the internal safety aspects of a given energy source.

* A very high potential for comparisons and better decision making support for more than one energy source reviewed if a CAS level 2 and 3 is analyzed.

* The versatility of the unique CAS levels 1, 2, 3 model for more than one energy source for on-line (living multiple energy source and safety-security model in an integrated unique model) operation. This feature is extremely useful for the use of the method to support decision-making.

* Very good possibilities of connecting the model with extended external risk related databases for on-line support to decision-making process, a process which could be defined as "Living PRA for a CAS system".

* Securing the energy supply has become very high on the global political agenda. DM is faced with multiple interconnected, interdependent, complex, divergent and competing factors that need to be monitored and assessed in order to practice good governance in the security of energy supply arena. To assist them in this task, systematic methods are needed that is capable of addressing multi-criteria decision-making for complex systems, such as the energy supply network.

2.2.2 RIDM specific methods

RIDM could used various tools as shown in Figure 2.

SES RISK is one specific tool developed based on and as part of QRA/PRA methods group used for some specific applications and some type of CAS, of which the evaluation of energy security is one of them, as shown in [14]

2.2.2.1 SES RISK - Goals and Objectives

SES Risk is a method that aims to capture the complexities encountered in the energy supply system by providing an integrated risk analyses approach, also accommodating multi-criteria decision making tools to assist decision-makers by providing a set of ranked risks and related uncertainties for the prioritization of options.

An initial low-resolution pilot model (SES-RISK) results proved that there are no fundamental modelling problems for the development and use of the method. SES RISK is able to support decisions on security of energy supply issues. In this respect it is:

- i. A systematic tool to evaluate the impact on risk of various challenges to complex systems, like energy chains and networks
- ii. A method capable to address multi-criteria decision-making

- iii. A method based on a model of the energy systems, which consider the fact that these systems have a high degree of interconnectivity, complexity, need to address divergent and competing objective functions
- iv. A method able to comply with a set of requirements as follows:
 - a. Interconnections between various subsystems to be modeled in such a manner so that and they can be identified and detailed,
 - b. The level of detail can be adapted to the existing information and considered in the results, due to the flexibility of the method,
 - c. There should be a method to identify uncertainties and a possibility of fast, traceable and flexible extensive uncertainty and sensitivity studies

2.2.2.2 SES RISK - Basis and Model aspects

SES Risk is based on definition of the CS and risk as presented in the previous paragraphs. The model is based on a generalized format of PRA (Figures 8 and 9), as already implemented in some applications. This approach on the model for a system of systems as one could consider the object of the security of energy supply task, allows us:

- i. To model complex systems and systems of systems with interdependencies
- ii. To derive results and answers to the decision makers questions in qualitative and/or quantitative format and with details not only with suggestions for further actions
- iii. To perform systematic traceable analyses, able to be modified if assumptions are changed
- iv. To evaluate the uncertainty of the analysis, including the modelling uncertainty induced by various assumptions
- v. To perform extended fast and user friendly sensitivity analyses
- vi. To perform analyses for various level of information available and with diverse databases (from numerical to expert judgment)
- vii. If Risk is used in the sense of a parameter combining both probability of occurrence of an event and the impact produced by it, then this approach can provide the results in both quantitative and qualitative manner with the evaluation of uncertainty.

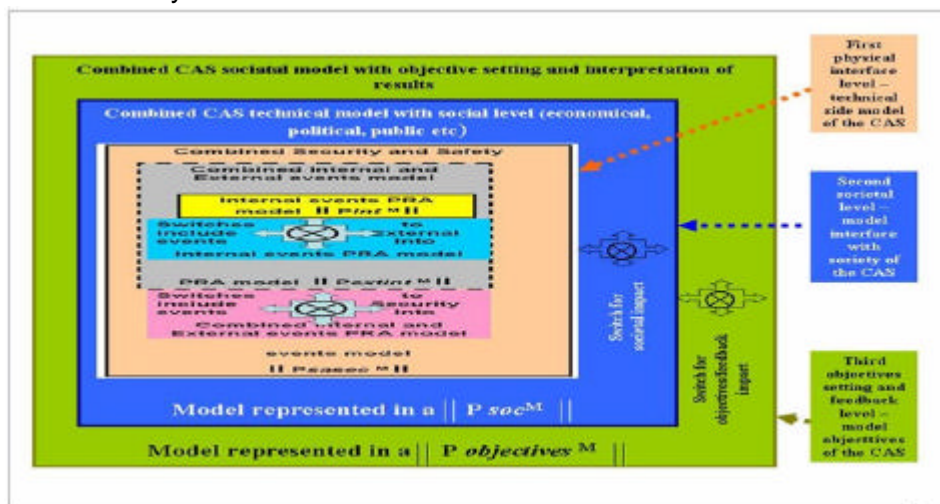


Figure 8. Representation of a 3 level CAS as used in SES RISK.

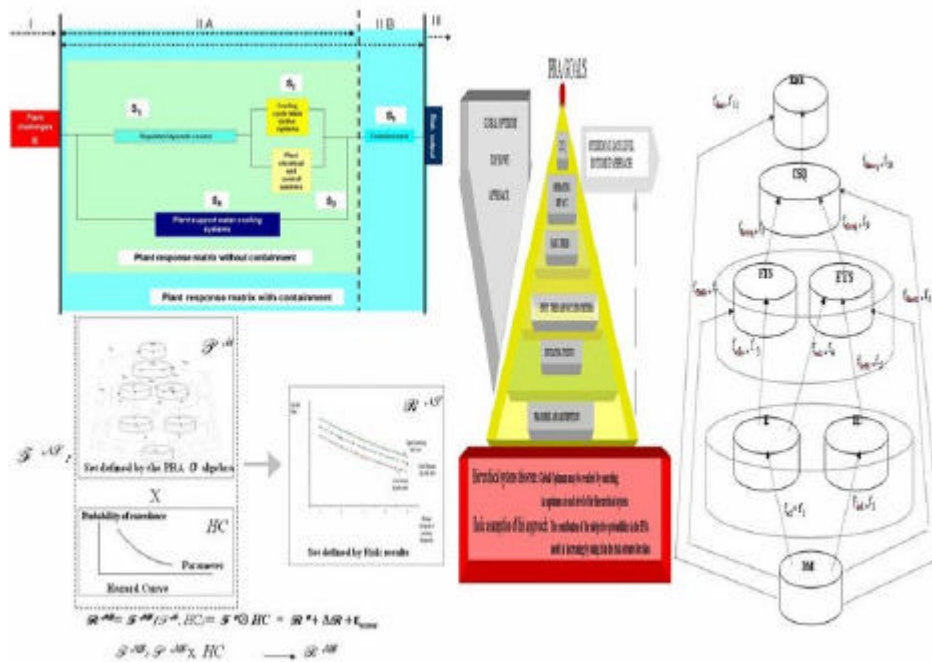


Figure 9. General representation of a PRA model and its metrics

The implementation of the above mentioned approaches assume that the energy systems, which are subject to a given security of energy supply problem (SESP) can be represented as in Figures 10 and 11.



Figure 10 General representation of a SESP model

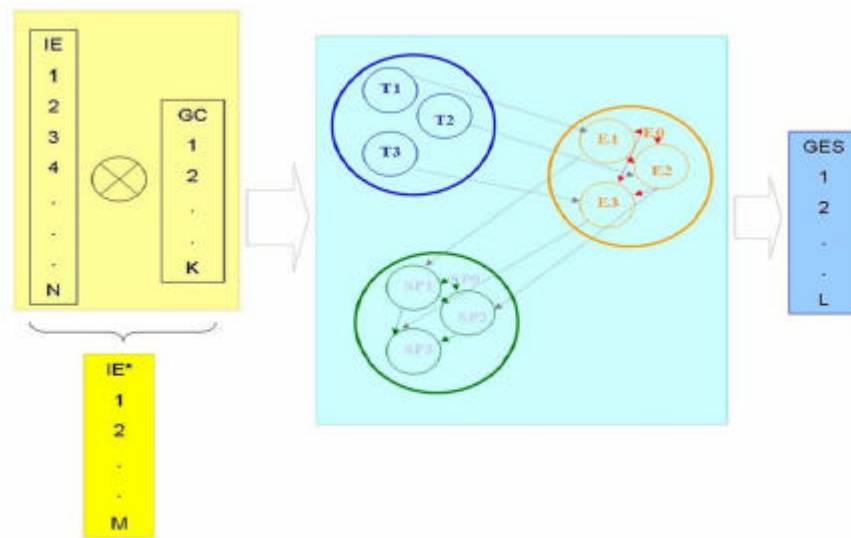


Figure 11 General representation of a SESP subsystems

In order to build a SES-RISK model, various groups of assumptions are made related to:

- interconnections between energy sources, grids and their sub-systems,
- assumptions about initial conditions (raw material self-sufficiency, supply/demand ratio, scale, etc.)
- assumptions about acceptability criteria (endstates) for energy sources and grids, sub-systems of each energy source and grid
- success criteria
- binning (grouping) rules for security of energy supply criteria.

In particular, it is assumed that there are three interconnected energy sources, which in turn, are linked to an energy raw material input grid (e.g. gas pipeline system) and to an energy customers' output grid (e.g. electricity). The three energy sources and grids are modelled as being composed of technical, economical and socio-political sub-systems (barriers) that are able to cope with technical, economical and socio-political challenges

2.2.2.3 SES RISK - Method and Implementation aspects

The method is defined by a series of calculations grouped into 5 steps:

- STEP1: Definition of the initial conditions
- STEP2: MAIN FLOW of the end states calculations
- STEP3: OBTAINING RESULTS from RiskSpectrum with the combination of events, which could lead to various end states for each energy system and grid and also to transition end states up to reaching the phase of final survivability states and definition of the objective functions groups.

- STEP4: POST PROCESSING MODEL RESULTS in which the results obtained with RiskSpectrum are prepared for decision-making type of tables for the end states calculated at the previous step.
- STEP5: INTERFACE WITH USERS AND REFORMULATION OF RESULTS AND RANKING. Restart of new iterations if needed and performance of extensive sensitivity analyses.

In order to perform these steps a series of assumptions are needed. They can be grouped into the following categories of assumptions on:

1. Interconnections between energy sources, grids and their sub-systems,
2. Initial conditions
 - a. raw material self-sufficiency,
 - b. supply/demand ratio,
 - c. scale etc.
3. Acceptability criteria (end states) for
 - a. energy sources and grids,
 - b. sub-systems of each energy source and grid,
4. Success criteria in the scenarios and in the systems/sub-systems behaviour
5. Binning rules for the definition of combination of states at each modelling level and for the transfer from one stage to another.

The main flow path of the method is represented in Figure 12.

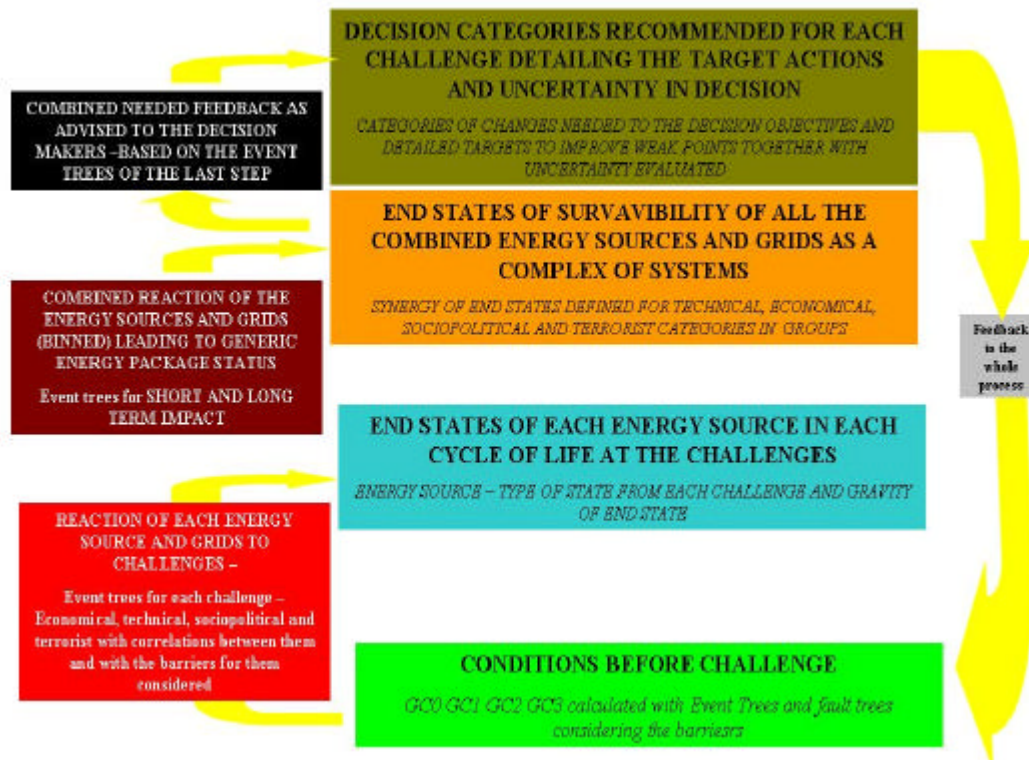


Figure 12 Schematic representation of the SES RISK flow path

The analysis is started by defining the conditions of the SESP before a given challenge had occurred. The list of possible groups of such initial conditions is shown in table 1.

Table 3. Initial Conditions Groups

GC0 – normal
GC1 – low disturbance
GC2 – medium disturbance
GC3 – high disturbance

The analysis continues with the building of the scenarios describing the SESP and failure trees of subsystems as identified initially. For each energy source and grid a set of end states are defined for all the challenges (technical, economical, terrorist and socio-political). They are defined and combined based on the adopted assumptions as mentioned before. A sample of such end states for each energy source and grid is shown in Figure 13. Figure 14 shows a representation of the interdependency matrix for those end states. This interdependency matrix is the basis for further combinations and grouping of the end states at intermediate level by using approach of the type shown in Figure 15 and 16. Scenarios are developed for the whole model and for each subsystem in order to analyse the model response to various perturbations (challenges -technical or social or economical etc.).

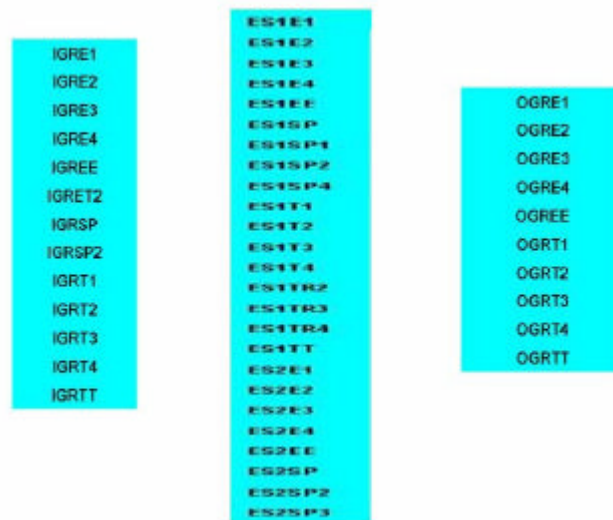


Figure 13. Sample of end states for energy sources and grids

End States Correlation Matrix + Binning Rules												
	T1	T2	T3	E0	E1	E2	E3	SP0	SP1	SP2	SP3	
T1	T1	0	0	Max	+	0	0	Max	+	0	0	
T2		T2	0	Max	0	+	0	Max	0	+	0	
T3			T3	Max	0	0	+	Max	0	0	+	
E0				E0	Max	Max	Max	Max	Max	Max	Max	
E1					E1	x	x	Max	+	x	x	
E2						E2	x	Max	x	+	x	
E3		Symmetric					E3	Max	x	+	x	
SP0								SP0	Max	Max	Max	
SP1									SP1	x	x	
SP2										SP2	x	
SP3											SP3	

Figure 14. Sample of end states for energy sources and grids interdependency matrix

The use of a computer code to combine the scenarios assures a fast and traceable calculation with possibility to friendly user interface and fast evaluations of any changes.

In order to define the survivability criteria a set of categories can be adopted (being also a possible subject for any further sensitivity calculations), which group them into larger groups defining the degree of the survivability of the whole set of systems composing the SESP. A sample representation of those survivability categories is shown in Figures 15 and 16.

SES - Specific Survivability Subgroup (SES-SSS)	SES-SSS short code	Short Description of General Survivability Group
SURV-T0	T0	Survivability with Technical aspects challenged - Low impact leading to Minor follow up corrective actions needed
SURV-T1	T1	Survivability with Technical aspects challenged - Medium impact leading to Some important follow up corrective actions needed
SURV-T2	T2	Survivability with Technical aspects challenged - High impact leading to Major follow up corrective actions needed
SURV-ESP0	E0	Survivability with Socio Economical or Public Interface aspects challenged - Low impact leading to Minor follow up corrective actions needed
SURV-ESP1	E1	Survivability with Socio Economical or Public Interface aspects challenged - Medium impact leading to Some important follow up corrective actions needed
SURV-ESP2	E2	Survivability with Socio Economical or Public Interface aspects challenged - High impact leading to Major follow up corrective actions needed

Figure 15. Sample of survivability categories for energy sources

Based on the results for each end states of energy sources, and survivability criteria at various levels, a set of calculation can be done to indicate the best groups of actions suggested to the decision makers in order to decrease the risks in a SESP case for a given challenge

SES - General Survivability Group (SES - GSG)	Short Description of General Survivability Group	SES - Specific Survivability Subgroup Combination (Binning)
SURV 0	Survivability Very Low Impact leading to no significant follow up corrective actions needed	T0
		E0
		E1
		T1
SURV 1	Survivability Small Impact leading to Minor follow up corrective actions needed	E2
		T2
		E0T1
		E0E1
		E0T1
		E0T0
		E0T1
		E1T0
SURV 2	Survivability Medium Impact leading to Some Important follow up corrective actions needed	E1E2
		E1T1
		E1T2
		E2T1
SURV 3	Survivability High Impact leading to Major follow up corrective actions needed	E2T2

Figure 16. Sample of general survivability categories for SESP

. The actions groups are binned into the following categories:

- NCO – Actions required leading to no change of objectives
- CO1 – Actions required leading to mild change of objectives
- CO2 – Actions required leading to important change of objectives
- TCO – Actions required leading to total/fundamental change of objectives

2.2.2.4 SES RISK - Results for Specific case of Security of Energy Supply

For a given case calculation the RIDM type of results are presented in a form illustrated in Figure 17.

		CO2 IMP		Impact rank	Information Entropy	Uncertainty results	Groups
163	ES1_OY2_SP_SYS_SW5F	Split fraction not considering switches for failures of Systems ES1 SP Cy2	1.00E-02	H	4.49E-05	L	I-HL
169	OGR_OY1_E_SYS2	Failures of System 2 OGR E Cy1	1.00E-02	H	3.61E-05	L	
175	ES2_OY3_SP_SYS2	Failures of System 2 ES2 SP Cy3	1.00E-02	H	2.65E-05	L	
194	ES1_OY2_SP_SYS1	Failures of System 1 ES1 SP Cy2 considering switches	1.00E-01	H	2.32E-05	L	
197	ES1_OY2_E_SYS2	Failures of System 2 ES1 E Cy3	1.00E-02	H	3.14E-06	L	
198	ES2_OY2_E_SYS2	Failures of System 2 ES2 E Cy3	1.00E-02	H	2.85E-06	L	
245	ES2_OY2_T_SYS_SW5F	Split fraction not considering switches for failures of Systems ES2 T Cy3	1.00E-01	H	3.76E-10	L	II-HM
73	ES2_OY2_E_SYS2	Failures of System 2 ES2 E Cy2	1.00E-02	H	2.42E-03	M	
74	OGR_OY2_SP_SYS2	Failures of System 2 OGR SP Cy2	1.00E-02	H	2.42E-03	M	
75	OGR_OY2_E_SYS2	Failures of System 2 OGR E Cy2	1.00E-02	H	2.42E-03	M	
76	ES2_OY2_SP_SYS2	Failures of System 2 ES2 SP Cy2	1.00E-02	H	2.42E-03	M	
77	IGR_OY2_E_SYS2	Failures of System 2 IGR E Cy2	1.00E-02	H	2.42E-03	M	
114	IE_S01_ES1_OY2_SF2	IE SP2 for SC1 ES1 Cycle2	1.00E-02	H	7.08E-04	M	
139	IGR_OY2_E_SYS1	Failures of System 1 IGR E Cy2	1.00E-01	H	1.72E-03	M	
143	OGR_OY2_E_SYS1	Failures of System 1 OGR E Cy2	1.00E-01	H	1.72E-03	M	
144	ES3_OY2_SP_SYS1	Failures of System 1 ES3 SP Cy2	1.00E-01	H	1.58E-03	M	
146	IE_S01_ES2_OY2_T2	IE T2 for SC1 ES2 Cycle2 (Operation)	1.00E-03	M	1.41E-05	L	III-ML
147	IE_S01_IGR_OY2_T2	IE T2 for SC1 IGR Cycle2	1.00E-03	M	1.41E-05	L	
148	IE_S01_OGR_OY2_T2	IE T2 for SC1 OGR Cycle2	1.00E-03	M	1.41E-05	L	
246	ES1_OY3_T_SYS1	Failures of System 1 ES1 T Cy3	1.00E-04	M	1.26E-12	L	
1	GC2_SF	Weight of choosing GC2	4.00E-01	H	3.65E-01	H	IV-HH
2	GC1_SF	Weight of choosing GC1	3.00E-01	H	3.30E-01	H	
3	GC3_SF	Weight of choosing GC3	2.00E-01	H	2.44E-01	H	
4	GC0_SF	Weight of choosing GC0	1.00E-01	H	1.14E-01	H	
5	ES1_OY2_E_SYS1	Failures of System 1 ES1 E Cy3	1.00E-01	H	1.01E-01	H	
41	IE_S01_IGR_OY2_TR1	IE TR1 for SC1 IGR Cycle2	1.00E-01	H	2.23E-02	H	
62	ES2_OY2_E_SYS_SW5F	Split fraction not considering switches for failures of Systems ES2 SP Cy2	3.00E-01	H	1.15E-01	H	

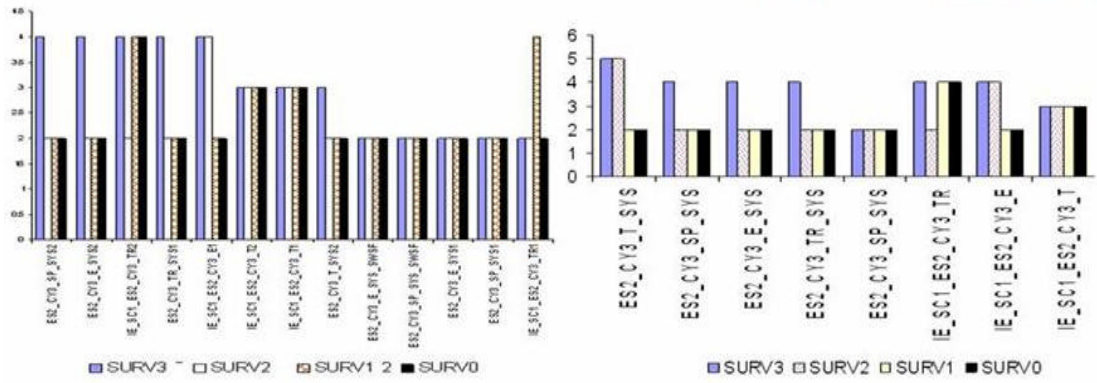


Figure 18. Sample final results to be submitted to the decision makers

Table 4. Options proposed to the decision makers for a given SES model

No	Sample 1 of a chosen challenge from the list identified on a high ranking and suggested actions for the decision makers
1	Challenge consists in a medium as intensity but firm public reaction to the energy source 1 – a potential dominant one over the energy cocktail in a given pre-challenge regional situation with average but manageable problems. The reaction appears while the energy source is on cycle 1 phase (R&D and pilot testing)
2	The dominant mechanisms leading to a possibility that the energy strategy will not survive as designed for this phase (R&D) are given by a combined failure of the second as importance energy source mechanisms assumed to cope with medium economic and sociopolitical challenges as a result of this challenge. The result consist in a situation of potential danger for the security of energy supply at this cycle phase due to impossibility to readapt to the situation without major readjustments
3	The adjustments to the systems requires medium impact reformulation of the system objectives and can be achieved if the energy source has its support assured socially politically and economically and the raw material grids to the new system and the energy distribution grids have approved and backed strategies. However since this decision strategy is of high uncertainty at this phase without sensitivity calculations, it could be that the decision maker will prefer to take action of medium impact on the whole problem but with higher degree of certainty, as for instance trying to have the financing mechanisms for the source 1 tests available even if there is some public reactions to it and also by putting more pressure from technical side so that to assure improving of the technical planning of the tests so that new technical or terrorist challenges to this source will not totally compromise the project and get it into the worst state of a need to change the whole strategy
4	The model provides the results of the challenges at a significant degree of uncertainty, which implies that further sensitivity analysis is needed to decrease it. If a strategy of a less impact elements fixing is chosen as shown above at 3, then a higher certainty of the results is available at this phase without more sensitivity analyses. However if the second approach will be adopted then the correction should be expected of less impact

The Fifth recommendation based on the experience for using
SES RISK as a QRA/PRA method to perform RIDM tasks

- The goal of using the tool in order to derive recommendations to support RG process by adequate analyses and also by adequate communication to the decision makers can be fully supported.
- The object/situation modelled (the type of CAS analysed) - in this case it is security of energy supply - is actually imposing the type of tools to be used. The tool has to be adequate to the CAS modelled. SESRISK , which is QRA/PRA type of approaches is adequate for SES modelling.
- There are specific benefits in possibility to evaluate not only risk ranking but also uncertainty calculations and periodical fast and traceable review for many sensitivity calculations given by the use of QRA/PRA type of calculations for specific CAS consisting of components modelling technical and scientific facets / relationships, as well as economic and social aspects.
- QRA/PRA type of analyses can comply with the requirement imposed for CAS systems of complex type during their use as RIDM tools.

3. RIDM – SAMPLES OF APPLICATIONS FOR RG EVALUATION

Other results confirmed also some of the recommendations presented so far. For instance in [16] the importance of actors in RG and the specifics of RIDM for various actors are also concluded.

As it was shown before RIDM use for security of energy supply can provide a set of important recommendations on specific aspects in which RIDM might be considered with priority in a complementary RG process.

On the other hand on going work on PRECP and DELIB [11;14] indicate on specifics for some CAS applications for those approaches.

Based on the situation mentioned above it is expected that a summary comparative review of specifics of using all three approaches (see Table 5) in the evaluation of three different CAS (as defined in Table 6) will indicate on more specific recommendations expected to detail the aspects of the complementary use in the RG process.

Table 5. Approaches used in a comparative evaluation of test cases defined in table6.

DELIB	<i>Acceptance is dependent on the existence of a deliberation process for the objective functions. Risks could be accepted / assumed as a result of deliberations</i>
PRECP	<i>Acceptance is expected because the decision is taken top down in a very conservative manner. The risks could be accepted / assumed as a result of legal actions</i>
RIDM	<i>Acceptance is expected based on evaluation of objective functions and various approaches in evaluation of risks for various actors perspectives</i>

Table 6. CAS cases used for the evaluation to support RG process

Case A	Highly controversial and emotional issue specially from public perspective. No risks accepted by public, no common agreement between the other two actors and significant difficulties to evaluate risk or other value functions	GMO
Case B	No major controversy on the issue and possible reach of acceptance for all actors but in a local area / country and no major difficulties to evaluate risk or other value functions	Mobile Phones
Case C	Agreement on some - safety /risk related aspects of the issue but possible problems in the implementation for all actors on the globe and no problems to evaluate risk or other value functions	SES

Results of the evaluation of cases A, B and C using RIDM, PRECP and DELIB lead to some conclusions, which have to be mentioned:

1. For a given combination of actors in the evaluation (Public-P, Industry-I and Government-G) the applicability of an approach depends in a high degree on the CAS evaluated (case A, B or C). If an approach is used for a CAS considered of a lower ranking from the point of view of applicability of the method then one should expect systematic biased results and conclusions/recommendations to be included in RG should consider this aspect. The conclusions on applicability could be made based on a process considering as many and diverse opinions as considered to be relevant for a statistics and/or decision theory based trusted statement. However the evaluation should consider also point 2 below.

Table 7. Applicability of various approaches to the cases from Table 6

Model/method	Code	PI	PG	IG	PGI
Deliberation/transparency-accountability	DELIB	Medium	High	Low	High
Precautionary Principle	PRECP	Medium	Medium	Medium	Medium
Risk informed decision making.	RIDM	Low	Low	High	Medium

Legend to Table 7

Medium applicability	High applicability	Low applicability	Able to adapt /reflect the needs
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2. For different combinations of actors (as shown in Table 7 and Figures 19 and 20) the ranking on importance from risk point of view of various cases is different due to an apparent bias on the method induced by the combination of actors using it. This confirms and refines the “user effect” of a given approach mentioned in point 1.

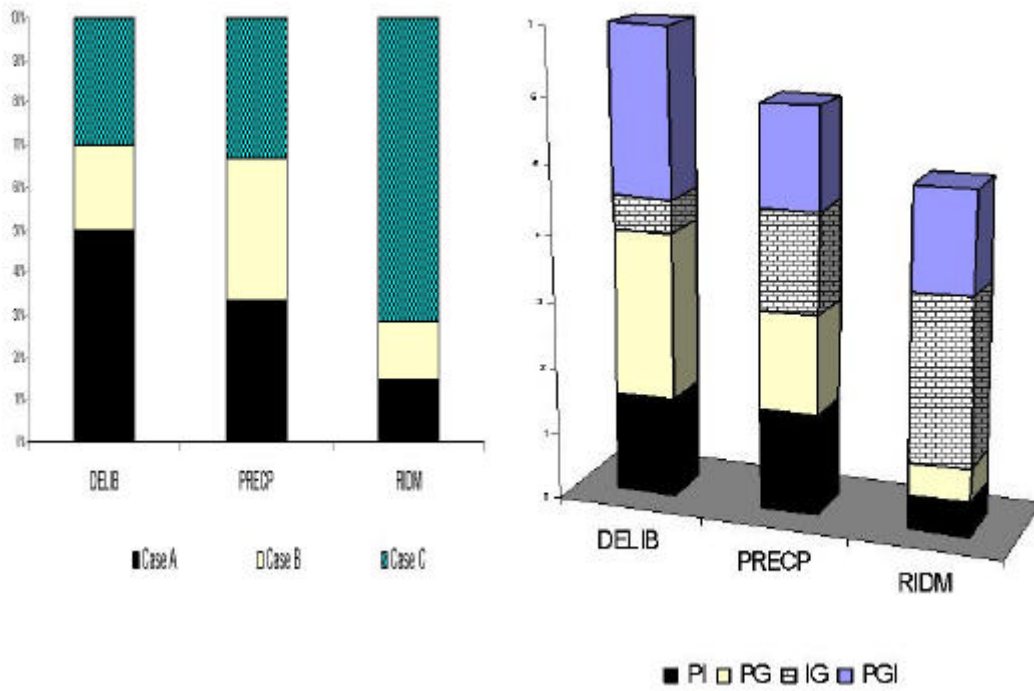


Figure 19. Ranking of the importance of risk issues for the cases A, B and C as evaluated with various approaches and for different combinations of actors

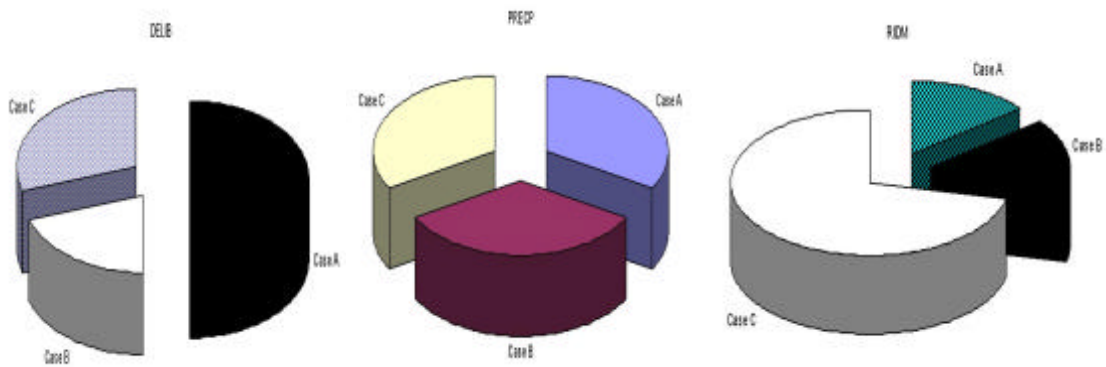


Figure 20. Ranking of the importance of risk issues for the cases A, B and C as evaluated for the participation of all actors using all three approaches (DELIB, PRECP and RIDM)

The Sixth recommendation based on the experience for the use of RIDM, PRECP and DELIB for RG

The use of a given approach in RG process is dependent in a very high degree on the "case type effect" meaning that typical CAS require typical approaches in order to get less and/or with a control bias evaluation

The use of a given approach in RG is dependent on a "user effect" meaning that the induced systematic distortions in the results depend on the users and they have to be known and complied with as part of the RG process.

4. RIDM – SOME CONCLUDING REMARKS

On the topic of the use of RIDM in RG process the present document assumed a priori and tried to demonstrate the details of the implications and conditions to exist for such assumption that the generic features of any approach required to support RG indicate on the expected complementarity of all of them.

From this perspective the present document had the goal to show some insights on how the RIDM could fulfil its task to support RG. The presentation of the general basis for RIDM, possible applicable method for RIDM and specific evaluation samples are included in order to detail the complementarity aspects.

Based on the review performed in the document the following recommendations related to specific aspects of complementarity of methods used by RG were underlined as follows:

4.1 On the issues related to the RIDM – RG interface

- a. RIDM could be a preferred approach when the evaluation is aiming at achieving its goals and objectives for various actors and at various levels of the CAS
 - i) Regulators decision makers
 - ii) Industry
 - iii) General publicdue to the fact that RIDM hierarchical evaluation is totally fit to RG goals and objectives
- b. RIDM is complying with one of the most important aspects of RG related to the interface on the public issues. Its hierarchical and structured approach

assumes by default the fact that the feedback between the three levels is assured by:

- i) Increasing openness
 - ii) Public participation and transparency
- c. RIDM is also capable to manage the main factors preventing the reach of openness and participation and transparency which have to be dealt with
- i) Increasing complexity of today's society
 - ii) Complexity of decision processes and the
 - iii) Complexity of the underlying factual basis

4.2 On the Risk-CS-DM interface

- a. DM process, which considers as an information source the aspects related to risk impact of a certain option chosen, is a RIDM process
- b. Based on the features described above the method QRA/PRA can be considered a suitable tool for the evaluation of risks and support to the decision making process QRA/PRA is considered a triple S method:
 - i) Systematic
 - ii) Structured
 - iii) Systemic

4.3 On the use of various tools of QRA/PRA type, which are amended for the interface with DM process:

it is considered highly desirable from the perspective of having a set of tools and results presented with the consideration of their uncertainty (credibility) and a clear traceable and easy to modify list of assumptions

4.4 On the use QRA/PRA type, which are amended for the interface with DM process SES RISK:

is considered preferable due to the fact that it is able to assure the following features:

- a. The important contribution to the final conclusions of comparing contributors to risk of societal aspects, in all methods used for comparison.
- b. The higher contribution of both security type of challenges (with and without barriers designed) by comparison with the internal safety aspects of a given energy source.
- c. A very high potential for comparisons and better decision-making support for more than one energy source reviewed if a CAS level2 and 3 is analyzed.

- d. The versatility of the unique CAS levels 1, 2, 3 model for more than one energy source for on-line (living multiple energy source and safety-security model in an integrated unique model) operation. This feature is extremely useful for the use of the method to support decision-making.
- e. Very good possibilities of connecting the model with extended external risk related databases for on-line support to decision-making process, a process, which could be defined as “Living PRA for a CAS system”.
- f. Security the energy supply has become very high on the global political agenda. DM is faced with multiple interconnected, interdependent, complex, divergent and competing factors that need to be monitored and assessed in order to practice good governance in the security of energy supply arena. To assist them in this task, systematic methods are needed that is capable of addressing multi-criteria decision-making for complex systems, such as the energy supply network.

4.5 On the experience for using SES RISK as a QRA/PRA method to perform RIDM tasks

- a. The goal of using the tool in order to derive recommendations to support RG process by adequate analyses and also by adequate communication to the decision makers can be fully supported.
- b. The object/situation modelled (the type of CAS analysed) – in this case it is security of energy supply - is actually imposing the type of tools to be used. The tool has to be adequate to the CAS modelled. SESRISK, which is a QRA/PRA type of approach, is adequate for SES modelling.
- c. There are specific benefits in possibility to evaluate not only risk ranking but also uncertainty calculations and periodical fast and traceable review for many sensitivity calculations given by the use of QRA/PRA type of calculations for specific CAS consisting of components modelling technical and scientific facets / relationships, as well as economic and social aspects.
- d. QRA/PRA type of analyses can comply with the requirement imposed for CAS systems of complex type during their use as RIDM tools

4.6 On the experience for the use of RIDM, PRECP and DELIB for RG

- a. The use of a given approach in RG process is dependent in a very high degree on the “case type effect” meaning that typical CAS require typical approaches in order to get less and/or with a control bias evaluation
- b. The use of a given approach in RG is dependent on a “user effect” meaning that the induced systematic distortions in the results depend on the users and they have to be known and complied with as part of the RG process.

4.7 On the risk modeling beliefs and myths

The demonstration performed so far in this document on CS/CAS, risk and related to it methods as for instance RIDM, as well as the impact on RIDM, is actually bound by a set of highly possible and expected systematic errors in modeling and building methods for those models, while discussing on risk and complex systems. Some results indicated on the need for high awareness on those systematic biases and the need to be prepared to implement actions to deal with systematic errors and paradoxes in the scientific quest of trying to model and evaluate risks [5;8;9].

- a. From this perspective not any model for CAS would be able to avoid systematic errors. It is suggested [5] to target a model for CAS and risk induced by a CAS, which complies with the following set of rules:
 - i) The model has to be developed on a basis of risk as a multiple yet convergent in a 3+1 hierarchical system, where 1 indicates the feedback loop.
 - ii) The risk measures have to be defined with various norms: classical, considering uncertainty etc
 - iii) Implementation of meaningful use of the risk notion for decisions has to be based not only on risk-benefit approach, but also on considering various goals adopted by various partners
 - iv) The risk theory has to be based on developing a model on the hierarchical system norm approach
 - v) A set of rules has to be defined for the use of model by various categories of users
 - vi) The objective and subjective models have to be defined in the model in a non conflicting method
 - vii) Scenarios with catastrophic failure of the whole theory behind the base line of the model have to be considered and defined.

- b. In mirror and correlated with the requests for a model able to cope with systematic errors the methods used for risk analysis should be able:
 - i) To be systemic, systematic and structured
 - ii) To be able to define structures of dynamic cybernetic interrelations between components with random character of challenges combined with intentional challenges and to solve nonlinear dynamic models, by defining what linearity means for a CAS
 - iii) To define the system as a whole, as being a result of the synergetic interfaces of its components and to define also the CAS interface with the environment
 - iv) To have a solution for the system control (like for instance distributed control, hierarchical control and/or external to the CS unitary control) and system management based on predefined objectives, as for instance

energy/substance balance or risk impact. Definition of objective functions for CAS like energy balance, information balance, system safety or security, system risk metrics etc. is very important and needs tested and/or testable methods directly or by benchmark exercises.

- v) To have a model and adequate method to solve the specifics of the cause-effect issue for a CAS, which is an aspect connected in its turn to others like definition of linearity, uncertainty and system structure modeling.
- vi) To be able to develop models and methods, which are dynamic themselves and with high flexibility in defining initial and boundary conditions.

c. Another issue to be mentioned is that it was assumed that a certain reasoning type of process was used. In various ways directly or indirectly the present scientific reasoning is based (as least for the CS/CAS quest as formulated so far) on the cartezian approach [16]. An illustration of this approach as it results from [16] is shown in Figure 21.

Goals and criteria	
R1	Goal of knowledge = formulate judgments (True & Fundamented) on Objects
R2	Objects =targets for which knowledge is undisputable & real
R3	Criteria for sound knowledge = get own intuition of the Objects
The Tool is defined by the rules	
R4	The tool is the Method
R5	Tool features are to Organize & Develop Gradually Increased Complexity Hierarchy of the Objects - GICHO
R6	Complexity Level Criteria (CLC) derivation process: > Define what is Simple = the reference CL_0 > Define the departure from CL_0 of Other Objects $\Delta CL = CL - CL_0$
Evaluate Completeness of knowledge	
R7	Evaluate all the objects in their interaction (synergetic mode) Conditions for a successful method – knowledge as a process (KP)
R8	The application of the Method has a Necessary and Sufficient condition - The existence of an Intuitive understanding of each Object, at all levels
R9	The KP has to start from CL_0 (Low Complexity Objects – LC_0) and get confirmation that it can be understood (by Intuition / Illumination) by the Subject
R10	Subject improves itself by practicing on LC_0
Results of KP	
R11	Subject has to use all MIND tools to achieve Knowledge > Reasoning > Imagination > Senses > Memory In order to > Perceive CL_0 by Intuition > Build Knowledge pieces starting from LC_0

Figure 21. Representation of the Cartesian scientific approach as per [16]

One of the comments on the remarkable features of this method we would suggest to pay a special attention for further review are Rules R10 and R11 indicating on an aspect less commented on our knowledge on Cartesian method, related to the role of feedback confirmation loop attributed to the use of all mind tools in order to achieve knowledge (which actually validate the role of integrative mind modeling approaches for all the types of methods).

That would be one of the first modern wonderful invitation to complementarity in all scientific quests, which was actually the same governing idea of this document.

d. However if the systematic modeling and methodological biases related to CS/CAS and risks are not avoidable (which is usually the case) then there is a set of beliefs and myths in this science of complex systems and related to its theory of risk, one could expect:

i) Generic myths as induced by scientific development [18]

- a) MyS1 Hypotheses become theories which become laws
- b) MyS2 Hypothesis is an educated guess
- c) MyS3 A general and universal scientific method exists
- d) MyS4 Evidence accumulated carefully will result in sure knowledge
- e) MyS5 Science and its methods provide absolute proof
- f) MyS6 Science is procedural more than creative
- g) MyS7 Science and methods can answer all questions
- h) MyS8 Scientists are particularly objective
- i) MyS9 Experiments are the principle route to scientific knowledge
- j) MyS10 All work in science is reviewed to keep the process honest

ii) Generic myths as induced by risk modelling [19]

- a) MyR1 "Risk" must have a single, well-defined meaning.
- b) MyR2 The severity of risks should be judged according to probability weighted averages of the severity of their outcomes.
- c) MyR3 Decisions on risk should be made by weighing total risks against total benefits.
- d) MyR4 Decisions on risk should be taken by experts rather than by laymen.
- e) MyR5 Risk-reducing measures in all different sectors of society should be decided according to the same standards.

- f) MyR6 Risk assessments should be based only on well-established scientific facts.
- g) MyR7 If there is a serious risk, then scientists will find it if they look for it.

In order to manage those sets of paradoxes generated by the beliefs and myths above mentioned one possible approach is to manage the gap between truth values of statements and the paradoxes as generated, as illustrated in Figure 22 [5] in an attempt to take decisions with known and/or manageable errors.

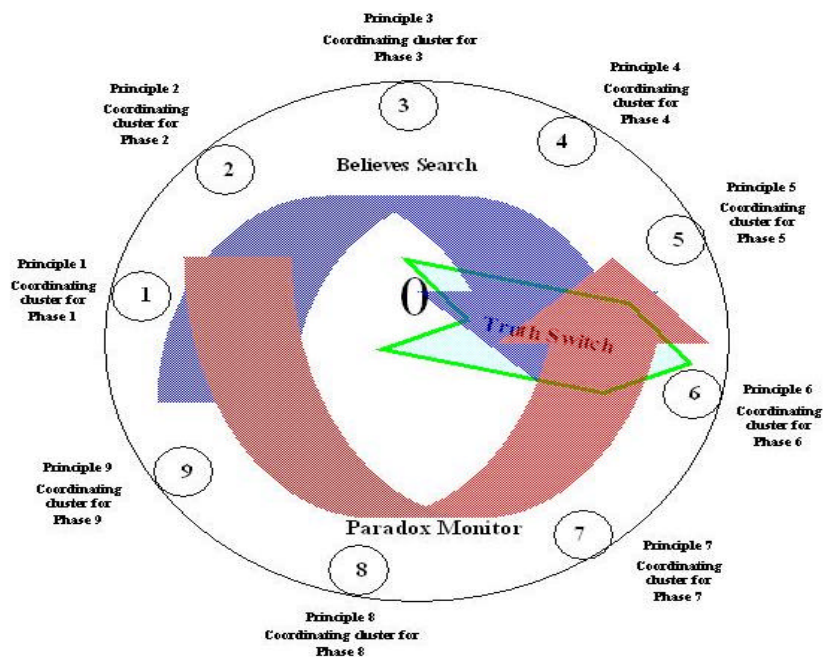


Figure 22 A proposed approach for the management of systematic bias of models in CS/CAS [5;8]

For specific cases a series of paradoxes and approaches to cope with them in CS/CAS were identified so far [5;8;9] and they are presented in Append1x 1

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Appendix 1 to RIDM and RG – Sample of paradoxes in some CS/CAS and proposed solutions to manage them

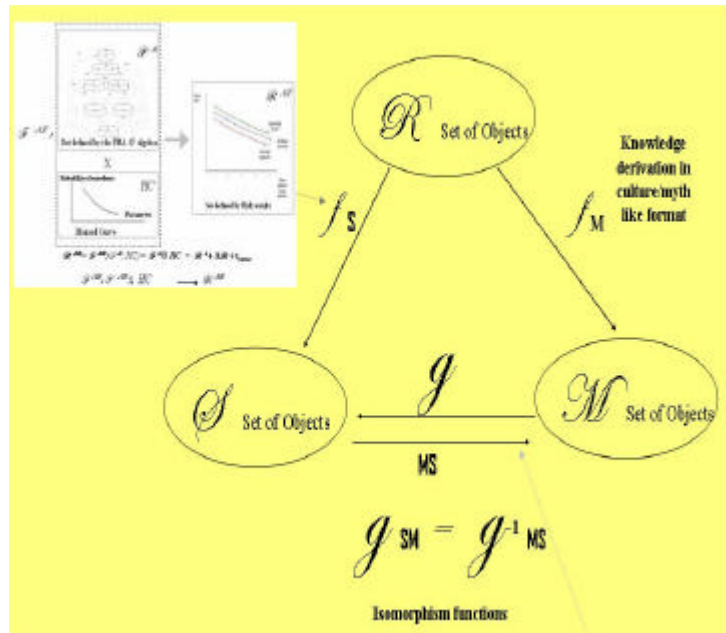


Figure A1.1 Knowledge and the myths generated by it

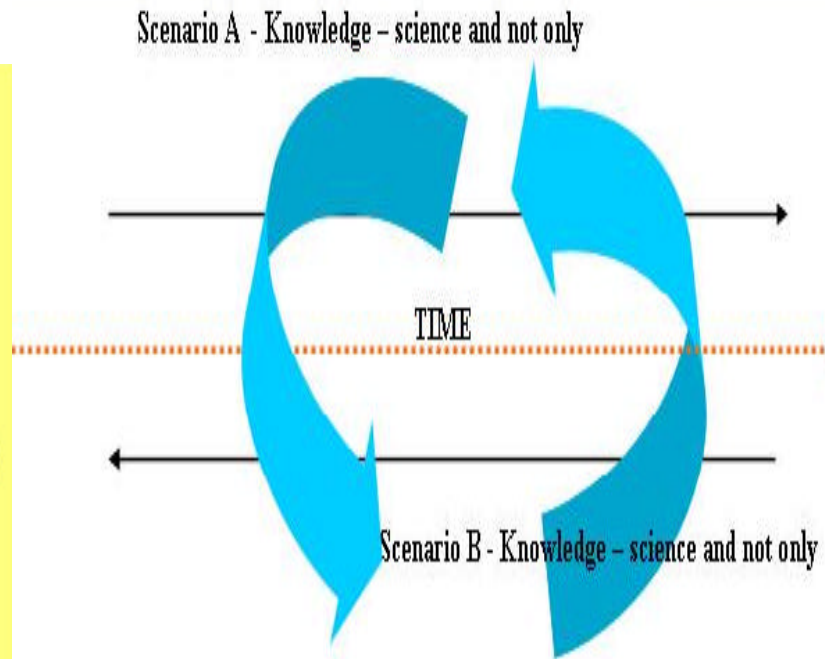


Figure A1.2 Non linearity of knowledge – time connections

Table A1.1 Sample of CAS modeling phases and main paradoxes

Phase	Main characteristic of the Phases in science evolution		Main governing principle of a given phase	Main features of the interface of governing principle, paradoxes and believes		Main characteristic of the Phases in CAS Risk modeling
1	Define the need	P1	An unique source	An isomorphism exists between the mythical thinking in general and the scientific thinking acting to solve Paradoxes	P1	Identify and use the unique source for the risk theory of CAS
2	Clarify the differences	P2	Basic science features as a dual Approach	Instinctive impulse exists to bring the issues to a duality in defining the truth, applicable criteria and methods for its evaluation and value of results	P2	Adopt a dual approach (risk-objective functions) to describe the issues of CAS
3	Develop main tools	P3	Creation of new in science governed by a triple way Approach	Creating the new in science has a triple facets in order to try to overpass the dual approach of the basics and look for the third option, starting from paradoxes	P3	Develop a method with triple facets approach for users

4	Check the stability of the theories	P4	Durability of a theory shown as robustness to paradoxes	Continue quest from phase 3 and check the science robustness on the embedded in it paradoxes	P4	Test the model on durability/stability to Paradoxes
5	Identify main believes preventing evolution	P5	Each historical stage is an engine powered by intuition and believes	Identify the believes behind the paradoxes identified in previous phases	P5	Identify the model development stages and potential believes leading to paradoxes
6	Refine and increase Usefulness	P6	For any theory has to be useful	Clarify and refine the value of the acquired set of Knowledge	P6	Define the value functions for the use of the model CAS
7	Attempt to merge tools	P7	God is not playing dice- Absolute and relative knowledge	Support the need for creating the new with merged tools in the attempt to make a synthesis of those ones appearing as fundamentally opposed	P7	Merge deterministic-probabilistic approaches in the model
8	Manage the built up	P8	Hierarchy and science theories structures involve the need for Management	Manage the gained corpus of knowledge in consolidation of the tools and results obtained so far.	P8	Develop the self regulating tools for management of the model itself
9	Attempt to solve the unsolved yet issues	P9	Irrepressible need to reach	Start systematic challenge of the existing paradoxes in a	P9	Reach the knowledge level of first iteration and proceed to the next review spiral

	and expand the object		perfection as a cause for restarting the whole cycle	final attempt to eliminate them from the built up achieved and clean the corpus of knowledge.		
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Table A1.2 Sample of CAS risk modeling and related to it possible systematic biases induced by generic science or specific risk modeling myths

	Main characteristic of the Phases in CAS modeling Risk	Main paradox	Risk Myths	General-science Myths
P1	Identify and use the unique source for the risk theory of CAS	The evaluation of CAS risk leads to the need for a unique theory based on the assumption that there is a unique source to describe. However the unification attempts lead to the reality that there are different possible approaches for the same CAS	MyR1 "Risk" must have a single, well-defined meaning.	MyS7 Science and methods can answer all questions
P2	Adopt a dual approach (risk objective functions) to describe the issues of CAS	The models and methods consider both the deterministic and the probabilistic approaches as describing correctly CAS. However they exclude each other in some areas as for instance the need for confidence possible to be obtained from deterministic reasoning and the uncertainty induced	MyR6 Risk assessments should be based only on well-established	MyS5 Science and its methods provide absolute proof

		by the probabilistic reasoning. In this way by merging two methods to get more clarity and confidence we can get in some CAS more uncertainty and vagueness	scientific facts.	
P3	Develop a method with triple facets approach for users	The combination of deterministic and probabilistic approaches implies allocation of subjective weights to a given judgement on a random variable, which generates values on qualitative statements	MyR2 The severity of risks should be judged according to probability weighted averages of the severity of their outcomes.	MyS3 A general and universal scientific method exists
P4	Test the model on durability/stability to paradoxes	Sensitivity and uncertainty analyses - model benchmarking checks the stability of the model to paradoxes. However the testing generates an acceptance of the initial paradigms of the model and methods by any cross check performed in order to see how stable the model is to paradoxes, because any theory can be verified with another tool subject in its turn to paradoxes.	MyRx V&V by benchmarking and feedback from operation are sufficient evidence to prove validity of a model	MyS4 Evidence accumulated carefully will result in sure knowledge
P5	Identify the model development stages and potential believes leading to paradoxes	Stages follow in principle one after another but it is not mandatory and assuming a smooth transition from one phase to another creates the paradox of unexplainable breaks appearing every time a fundamental change happens	MyR7 If there is a serious risk, then scientists will find it if they look for it.	MyS2 Hypothesis is an educated guess AND MyS9 Experiments are the principle route to scientific knowledge
P6	Define the value functions for the use of the model CAS	Value function depends on actors, cases etc and defining a value functions creates a limitation not intended for CAS by the initial goal to get a global set of values	MyR 3 Decisions on risk should be made by weighing total risks against total	MyS8 Scientists are particularly objective

			benefits.	
P7	Merge deterministic-probabilistic approaches in the model	Merging deterministic and probabilistic models lead to the intent to have certainty on uncertain by default phenomena (probabilistic ones) and viceversa for deterministic ones which is in conflict with the intent of merging to eliminate contradictions	MyR5 Risk-reducing measures in all different sectors of society should be decided according to the same standards.	MyS10 All work in science is reviewed to keep the process honest
P8	Develop the self-regulating tools for management of the model itself	Management of risk model leads to need to freeze the model and/or change it in controlled steps and procedural manner, which could actually generate the validation by procedures of all the systematic assumptions and errors.	MyR4 Decisions on risk should be taken by experts rather than by laymen.	MyS 6 Science is procedural more than creative
P9	Reach the knowledge level of first iteration and proceed to the next review spiral	The restart of the process is done in the same steps after the accumulation of the paradoxes making impossible use of the theory assuming that evolution could give a solution, while it is clear that a revolution could give it	MyR7 If there is a serious risk, then scientists will find it if they look for it.	MyS1 Hypotheses become theories which become laws

Table A1.3 Sample of CAS modeling and paradoxes

Phase	CODE	Main characteristic of the Phases in CAS Risk modeling	PARADOXES		Unknown/Unformulated assumptions leading to paradoxes	
			Main paradox	Main paradox-short	Risk Myths	General-science Myths
1	P1	Identify and use the unique source for the risk theory of CAS	The evaluation of CAS risk leads to the need for a unique theory based on the assumption that there is a unique source to describe. However, the unification attempts lead to the reality that there are different possible approaches for the same CAS	CAS Unique source--->Unitary theory--->Multiple diverse risk facets to model	MyR1 "Risk" must have a single, well-defined meaning.	MyS7 Science and methods can answer all questions
2	P2	Adopt a dual approach (risk-objective functions) to describe the issues of CAS	The models and methods consider both the deterministic and the probabilistic approaches as describing correctly CAS. However they exclude each other in some areas as for instance the need for confidence possible to be obtained from deterministic reasoning	Deterministic vs probabilistic --->Impossible that only one will cover CAS risk --->Do we have to accept theory based on "Contraria non contradictoria sunt?" N.Bohr	MyR6 Risk assessments should be based only on well-established scientific facts.	MyS5 Science and its methods provide absolute proof

3	P3	Develop a method with triple facets approach for users	The combination of deterministic and probabilistic approaches implies allocation of subjective weights to a given judgement on a random variable, which generates values on qualitative statements	CAS risk in deterministic & probabilistic approaches need "Meta - Logic" to combine them---->The third facet cannot be from inside the theory and new level is required	MyR2 The severity of risks should be judged according to probability weighted averages of the severity of their outcomes.	MyS3 A general and universal scientific method exists
4	P4	Test the model on durability/stability to paradoxes	Sensitivity and uncertainty analyses - model benchmarking checks the stability of the model to paradoxes. However the testing generates an acceptance of the initial paradigms of the model and methods by any cross check performed in order to see how stable	Detailed list of assumptions lead to paradigms --->Paradigms help building systematically models ---> create systematic errors---> Check of model robustness gets into its reverse action	MyRx V&V by benchmarking and feedback from operation are sufficient evidence to prove validity of a model (Godel's theorem)	MyS4 Evidence accumulated carefully will result in sure knowledge
5	P5	Identify the model development stages and potential believes leading to paradoxes	Stages follow in principle one after another but it is not mandatory and assuming a smooth transition from one	Set of CAS risk paradigms---> Isomorphism from set of believes ---> Decision to know the unformulated	MyR7 If there is a serious risk, then scientists will find it if they look for it.	MyS2 Hypothesis is an educated guess AND MyS9 Experiments are the principle route to scientific

			phase to another creates the paradox of unexplainable breaks appearing every time a fundamental change happens	assumptions leads to assertions assumed true		knowledge
6	P6	Define the value functions for the use of the model CAS	Value function depends on actors, cases etc and defining a value functions creates a limitation not intended for CAS by the initial goal to get a global set of values	Define value function for clarification of CAS risk model----> Leads to limitations not intended for CAS while setting up the initial goal	MyR 3 Decisions on risk should be made by weighing total risks against total benefits.	MyS8 Scientists are particularly objective
7	P7	Merge deterministic-probabilistic approaches in the model	Merging deterministic and probabilistic models lead to the intent to have certainty on uncertain by default phenomena (probabilistic ones) and viceversa for deterministic ones which is in conflict with the intent of merging to eliminate contradictions	Merge two approaches deterministic-probabilistic to get a better tool ----> The result is a tool with difficult to evaluate degree of assuring the certainty level expected by users	MyR5 Risk-reducing measures in all different sectors of society should be decided according to the same standards.	MyS10 All work in science is reviewed to keep the process honest

8	P8	Develop the self-regulating tools for management of the model itself	Management of risk model leads to need to freeze the model and/or change it in controlled steps and procedural manner, which could actually generate the validation by procedures of all the systematic assumptions and errors.	Try to solve theory merging issues by "theory managerial issues"=management of theory -----> Induces more uncertainties and leads to worsening of the initial "uncontrolled " phase	MyR4 Decisions on risk should be taken by experts rather than by laymen.	MyS 6 Science is procedural more than creative
9	P9	Reach the knowledge level of first iteration and proceed to the next review spiral	The restart of the process is done in the same steps after the accumulation of the paradoxes making impossible use of the theory assuming that evolution could give a solution, while it is clear that a revolution could give it	The tend to perfection lead to a set of paadoxes making unusable the results ---> New reviews and cycles are needed	MyR7 If there is a serious risk, then scientists will find it if they look for it.	MyS1 Hypotheses become theories which become laws

Table A1.4 Sample of CAS modeling summary of issues, paradoxes and actions suggested to manage them

Phase	CODE	Main characteristic of the Phases in CAS modeling Risk	SUMMARY OF ISSUES AND KEY WORDS/ACTIONS		
			PARADOX	BELIEF	ACTION TAKEN IN THE INVESTIGATED CASES

1	P1	Identify and use the unique source for the risk theory of CAS	Unique source modelled with integrated method leads to the need to diversify definitions of objective functions	It is assumed that there is a unique definition for risk and the risk science has an unique and unitary approach to give all the answers	Model DIVERSITY of objective functions for CAS metrics and use HIERARCHY for its structure looking for OPTIMUM at each Hierarchical level
2	P2	Adopt a dual approach (risk-objective functions) to describe the issues of CAS	Deterministic versus probabilistic approaches as complementary approaches seem to cope with the dual features of CAS risk models, but their use creates paradoxes if the applicability for each of them is not defined	It is assumed that the well established scientific facts showing both random data and deterministic data used in a scientific manner could provide support for certitude by using risk assessments	The APPLICABILITY AREAS of deterministic and probabilistic parts in the CAS model and in the decision module to be CLEARLY defined and used
3	P3	Develop a method with triple facets approach for users	Combine deterministic and probabilistic by using weights in judgements on random variables generates numerical results for which credibility depends on a solution not at the level of simple combination between the two type of data(deterministic and probabilistic)	It is assumed that in the case of risk analyses a scientific method of universal use exists to evaluate severity of risks by judging them according to their probability and the outcomes/damages produced	Use NUMERICAL and LOGICAL functions as SWITCHES and CONNECTORS between the deterministic and probabilistic part of CAS models and their metrics.
4	P4	Test the model on durability/stability to paradoxes	Test the model in order to check its stability at paradoxes identified up to this phase, which results in	It is assumed that by using carefully chosen experience and model results one can derive	Use SPECIAL sensitivity analyses phase to define the sensitivity to unseen/not clearly

			a closed logic loop of defining the reference case while remaining in the limits of the model itself.	objective results proving the validity of results for the given CAS model	formulated assumptions embedded in the model based on their reflection in the paradoxes. In the screening process of those issues use DIVERSE methods not included so far in CAS model
5	P5	Identify the model development stages and potential leading paradoxes	Even if in principle a specific CAS model could be in one of the nine stages and even if they follow each other, their duration, intensity and degree of challenge of the paradoxes at each phase differ from one CAS type to another the causal approach of identification of the believes behind the paradoxes for each phase leads to challenges to the cause-effect approach	It is assumed that by using educated guesses and experiments scientists can find and evaluate any significant risk due to the objectivity and other specific features of science.	Perform a full inventory of identified PARADOXES in CAS model and the possible BELIVES generating them in order to have a better understanding of the CAS model bias and DEFINE the CAS REFERENCE model for further analysis
6	P6	Define the value functions for the use of the model CAS	The CAS model is built for a given set of objective functions and the metrics of this model is expected to include risk, which usually is not one of the intended goals for the user	It is assumed that based on the objectivity of science and the approach in risk analyses to evaluate risks against benefits the results could be used as such in decision making	Identify the rules for the post-processing of risk analyses results in order to be used in the decision making process, by defining the place and desirability for the user of RISK INFORMED DECISION MAKING - a module to be

				process	added to the actual results from risk analyses for CAS models
7	P7	Merge deterministic-probabilistic approaches in the model	Merging deterministic and probabilistic models lead to the intent to have certainty on uncertain by default phenomena (probabilistic ones) and certain deterministic ones leads to conclusions having problems of logic consistency	It is assumed that by using a scientific method, which is honest and objective and by using risk reducing measures in all sectors of society (any type of CAS model) the combined use of weel proven tools in all science of analysis / deterministic and synthesis/ probabilistic approaches is assuring success in CAS modeling.	The merging action of deterministic and probabilistic approaches in CAS risk models id accompanied by an IMPROVED set of LOGICAL construction of the formulations of results and modules merging the two approaches
8	P8	Develop the self regulating tools for management of the model itself	Management of risk mode leads to managerial/procedural control in order to limit the uncertainty in the real process of CAS evaluation. However this action is in itself creating new systematic assumptions and errors and is shadowing the ones	It is assumed that science is more procedural than creative (at least for this type of activity) and the decisions themselves have to be made by trained staff and scientists	Check the "IMPURIFICATION" of the CAS model without risk managerial actions considered and INCLUDE their potential distortion into the model

			accumulated up to this phase		
9	P9	Reach the knowledge level of first iteration and proceed to the next review spiral	The completion of a CAS in nine cycle phases and its implementation reveal the need to restart the process for a better theory	It is assumed that science is evolving based on laws which appear by the transformation of hypotheses into theories, which become laws and for any CAS in this case if there will be a real risk then the scientists will find it	Restart the cycle of modeling even if there is no user request for it since there is always a need to have full coherent answers to ALL PARADOXES encountered, even if they seem of no interest for the user and/or scientific community.