Precautionary Principle in Managerial Decision-Making: a Socio-Cognitive Engineering Perspective

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Our work is aimed at the modelling of the **Precautionary Principle (PP)** in the context of real-world threats and complex managerial decisions. Human socio-cognitive decision-making is critical for Large Complex Critical Infrastructure (LCCI) networks, which are vulnerable to a cascading effect, when the losses' generation propagates from one domain to another and between different, interdependent LCCI systems.

Critical infrastructures' safety and security depend not only on technological design solutions and installed protective hardware and software systems. Protection of critical infrastructures is a responsibility of decision-makers acting also at a very high (political) level (Ezell 2007), however protection of infrastructure elements remains a responsibility of organizations, who own them and their employees (individual decision-makers) (Jones 2007).

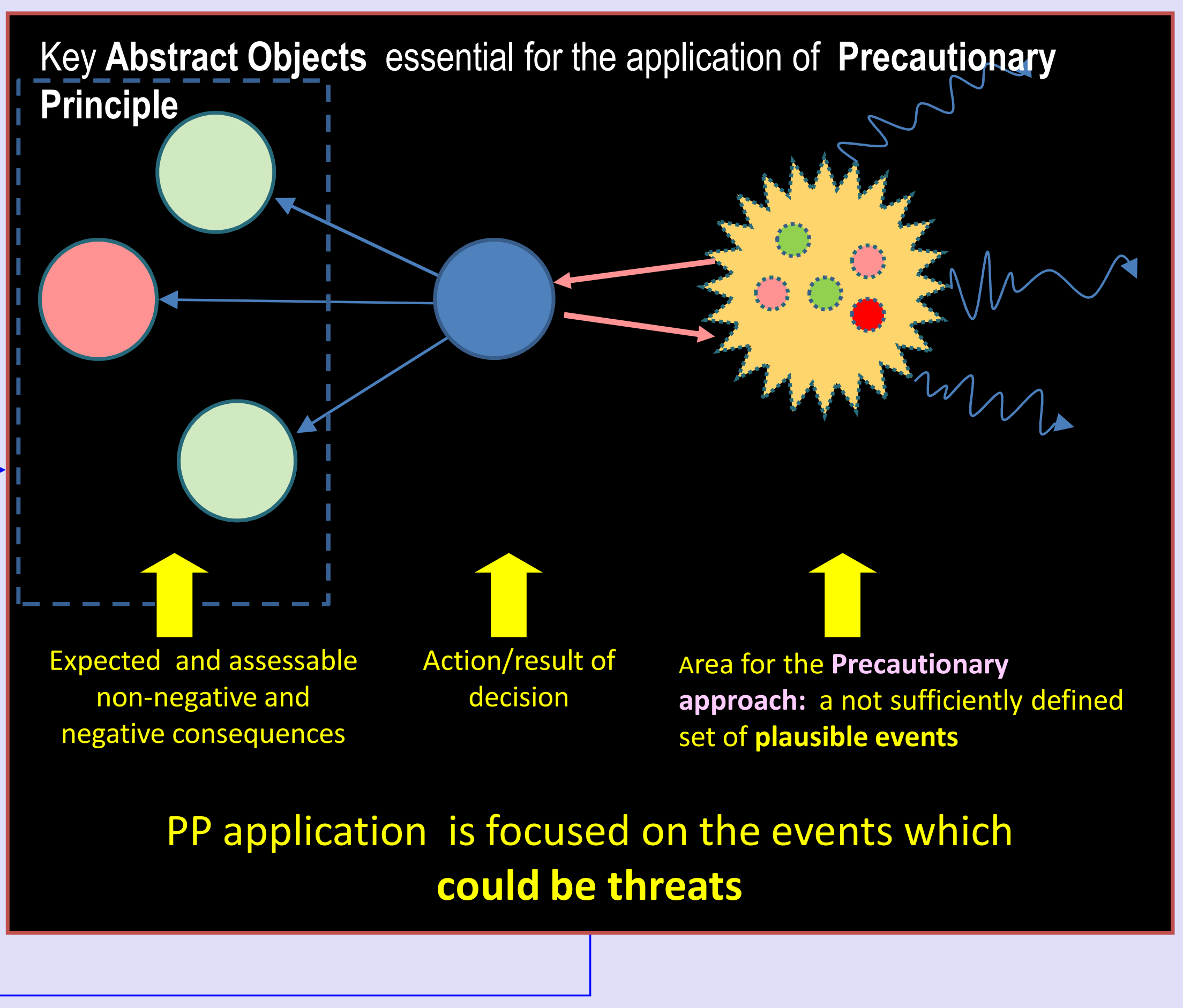
Precautionary Principle

A concept developed strongly since the 1980s

Advises to take measures aimed at avoidance of unwanted events in case of insufficient data and knowledge as to their severity or occurrence

Is introduced in many legal documents

Influences risk management policies.


Key **Abstract Objects** essential for the application of **Precautionary Principle**

Expected and assessable non-negative and negative consequences
Action/result of decision
Area for the **Precautionary approach:** a not sufficiently defined set of **plausible events**

PP application is focused on the events which **could be threats**

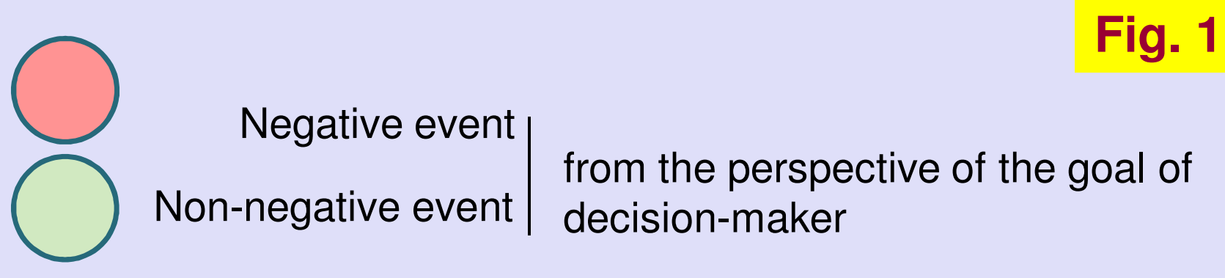


Fig. 1

Since there are many versions of PP, as well as many legal approaches to the concept of risk itself, the main goal of the authors was to propose a computational modelling framework describing when PP should be applied and the way of its domain-specific specialization.

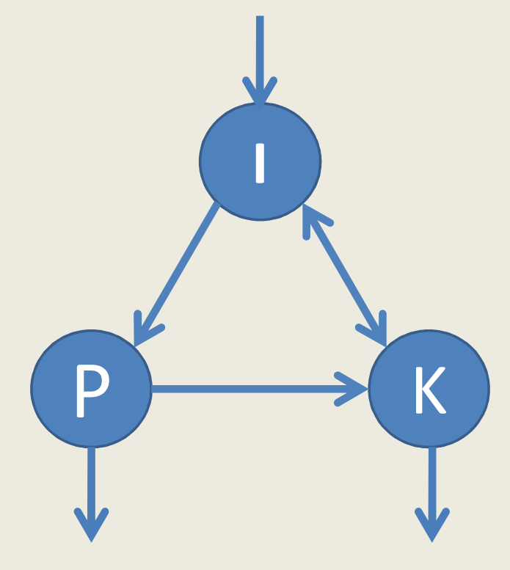
This task requires the distinguishing of the classes of situations where PP is suggested, and a sufficient formalization of the PP rule in the decisional context.

The model is constructed using to the Top-down Object-based Goal-oriented Approach (TOGA) meta-theory. The specific socio-cognitive property of this approach is the assumption of the perspective of a concrete **intelligent agent** (individual or group of intelligent beings) IA, which is involved in a given intervention-oriented decision-making in a pre-selected domain of his activity.

The TOGA meta-theory, as a meta-knowledge conceptualization tool, has been applied to the knowledge ordering in several identification and specification complex, interdisciplinary problems (Gadomski 1994), (Gadomski et. al. 2001), (Gadomski 2002), (Gadomski 2007). It is based on the set of: top-axioms, modelling paradigms, top-models and methodology.

In this work we need to integrate *identification* and *specification* perspective (where identification relates to existing objects and specification is focused on the design of not existing yet systems/processes), because, on the one hand we recognize real decisional situation and on the other, we propose a concert structured **response modelling process.**

According to the TOGA meta-theory, decisions of an intelligent agent depend on its/his **Information, Preferences** and **Knowledge (IPK)**. IPK are modificabile and can also be interdependent:



- **Information** (I): data which represent state of the recognized agent's domain of activity
- **Preferences**, (P): ordered relations among states of the domain of activity of the agent which indicate a state with higher utility (preferred)
- **Knowledge**, (K): everything that transforms (quantitatively/qualitatively) information into other information or into knowledge or a preference.

Fig. 2

Decomposition of generic decision-making based on the IPK evaluation process

Proposed stages of the decision-making:

1. Reception of information about an event

The $\mathbf{I_0}$ on the scheme denotes any new information, the agent receives. Thus, the scheme can depict a situation in which no losses are generated (a neutral situation) and an emergency situation, where the emergency manager receives new **I** relevant in his situation.

2. Situation assessment

The situation assessment stage is presented at level 2 of fig. 3 and in detail fig. 4. It comprises of following stages:

- processing of information with static model **K** (acquisition of information about current domain state)
- processing of information with dynamic model **K** (acquisition of information about possible future domain states).

3. Evaluation of possessed information and knowledge from the point of view of agent's preferences – this stage comprises of following substages:

- Evaluation of the content of IPK
- Evaluation of the amount of IPK
- Evaluation of quality of IK

4. Making the decision

At this stage of decision-making, the agent is able to determine whether the situation requires the application of PP and decides about actions (**A**) to be taken. The choice of **A** depends on several factors, such as *losses* caused by predicted event or their likelihood. Besides it depends on generalised, relative cost of current **A**. Depending on the level of decision-making these cost can encompass economical, political, ethical, cultural, personal costs. They are assessed subjectively at the moment of making the decision, and connected with spatial and temporal perspective of the decision maker, who has to make a meta-decision about whether possible action can be carried out within certain amount of time.

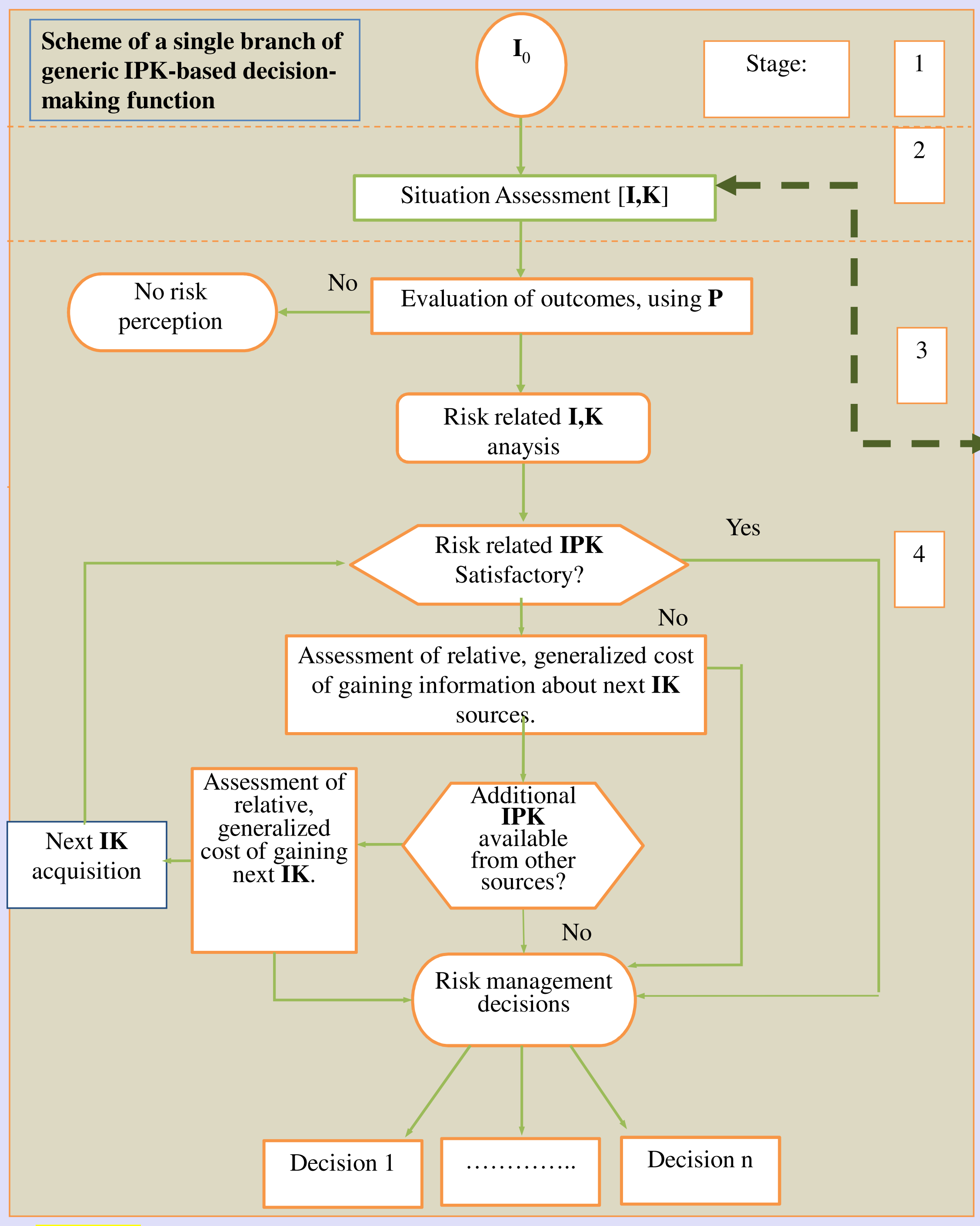
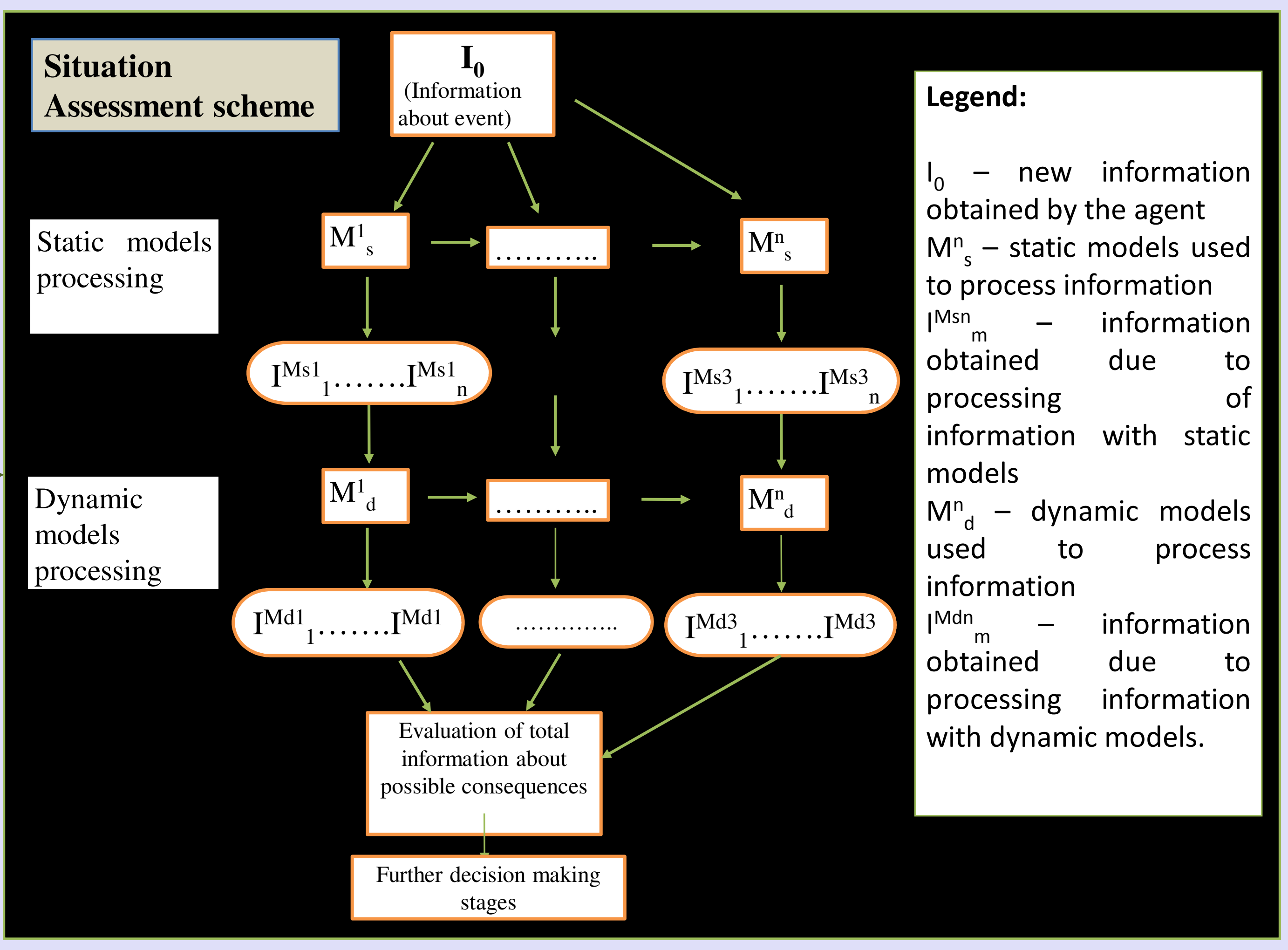

Scheme of a single branch of generic IPK-based decision-making function
I_0
Stage:
1
2
3
4
Situation Assessment [**I,K**]
No
No risk perception
Evaluation of outcomes, using **P**
Risk related **I,K** anaysis
Yes
Risk related **IPK** Satisfactory?
No
Assessment of relative, generalized cost of gaining information about next **IK** sources.
Next **IK** acquisition
Assessment of relative, generalized cost of gaining next **IK**.
Additional **IPK** available from other sources?
No
Risk management decisions
Decision 1
…………..
Decision n

Fig. 3


Situation Assessment scheme
I_0 (Information about event)
Static models processing
Dynamic models processing
M^1_s
………..
M^n_s
I^{Ms1}_1…….I^{Ms1}_n
I^{Ms3}_1…….I^{Ms3}_n
M^1_d
………..
M^n_d
I^{Md1}_1…….I^{Md1}
…………..
I^{Md3}_1…….I^{Md3}
Evaluation of total information about possible consequences
Further decision making stages

Legend:

I_0 – new information obtained by the agent

M^n_s – static models used to process information

I^{Msn}_m – information obtained due to processing of information with static models

M^n_d – dynamic models used to process information

I^{Mdn}_m – information obtained due to processing information with dynamic models.

Fig. 4

As follows from our decomposition, in order to apply the PP, the agent has to determine that:

- the expected event can be considered a threat
- **I** or **P** or **K** are insufficient to assess risk normally

The PP applicability: conclusions

Therefore PP can be first applied only at level 4 of the scheme

The precautionary approach cannot be taken solely at the level of decision-maker. He has to possess a **proper normative and organizational** framework. That is, why the PP has to be applied also within the **legislation**, in order to provide the agent with a proper set of **P** and maintain an efficient flow of **I** and **K**. Legislation has to contain directives as to the application if the PP by the agent. Improper legal framework can strongly contribute to loss increase when a threat becomes apparent, because such framework influences the decisions made by multiple agents, which, if taken wrongly, may cause loss accumulation.

These considerations are critical for LCCI risk management policies, where decisions about the functioning of interdependent critical networks (electrical, telecommunications, etc.) have to be made under **time constrains** (Bologna, 2003). If the decision cannot be postponed, the issue of a **quick access to critical I** and **K** becomes particularly important as well, **as clear distribution of competencies.**

Hence, paradoxically, the most important precautionary measure in management of risk in LCCIs is **narrowing the field for PP application at decision-maker level** as much as possible. These measures allow saving a valuable resource in LCCI management – **the time**. Improper application of PP can strongly decrease the efficiency of decision-making or even stop the process.

The proposed decomposition allows to develop a computer program which could be used to simulate the decision-makers' behaviour. Such a problem could support already existing LCCI simulators.

The presented study has a preliminary character. It has been performed in the frame of research and development projects: EU IRRIIS (Integrated Risk Reduction of Information-based Infrastructure Systems), the Italian national project CRESCO (Centro computazionale di RicErca sui Sistemi COmplessi - subproject: Socio-Cognitive Modelling for Complex Socio-Technological Networks), and the ENEA's project on the vulnerability of large technological and energy networks.

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More information are included in the full paper, available in the Proceedings of the CRITICS2008 Woekshop, Rome, Oct.2008.

See also CRESCO-SOC-COG web: http://erg4146.casaccia.enea.it/SC-CRESCO