Scenario Formulations and Integrated Approach in Decision Support System Design

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Abstract The basic concept of the integrated approach in designing multidisciplinary decision support systems (DSS) is discussed. The denotation of integrated DSS based on the principle of holism is proposed in the present work. The genesis of the 'decision making by scenario formulation' concept in the DSS design is traced. The emphasis of this study highlights conceptual differences between scenarios and arbitrarily selected what-if constructions. The primary question considered in this work concerns principles of scenario formulation within the integrated approach.

1. Introduction

Scenario formulation is a basic step in the DSS development. It concerns all types of DSS but is a matter of special importance in the multidisciplinary DSS for integrated assessment. The problems concerning the integrated assessment approach and scenario formulation have been widely discussed in the literature over the last twenty years (Schoute *et al.*, 1994). It is an advantage for a DSS for integrated assessment to fall into the class of integrated/holistic systems. The present paper examines the genesis of the terms mentioned above and investigates the junction point of these two problems: integrated assessment and DSS scenario formulations. In other words, the major aspects of DSS development addressed in this paper are

- What is an integrated approach? and
- What is an appropriate structure for the DSS scenarios formulated within this approach?

How a multidisciplinary DSS (in the sense of employing the manifold potentials of different disciplines in one unifying construction) becomes an integrated DSS is a very important problem. A definition of the integrated approach in DSS design is proposed in this work. This definition is conceptually based on the principle of holism. Thus, the DSS becomes integrated or holistic if qualitatively new knowledge, irreducible to the sum of knowledge provided by each of the system's components, is supplied by this system. The meaning of the term 'qualitatively new knowledge' is discussed in this paper.

Another major task of this work is to consider some basic principles of scenario formulation within an integrated DSS. An attempt to formulate the scenario concept made it necessary to identify definitions of some basic terms from the DSS development vocabulary, such as 'stakeholder' and 'scenario'. Definitions of these terms are considered below in the text.

2. Integrated approach and integrated assessment

2.1 Background

It is important to formulate a difference between the integrated assessment and the integrated (in the sense of holistic) approach because the phonetic proximity is often misleading. The first term is used to refer to the multidisciplinary analysis of a broad problem, for instance, the sustainable development of some regions or the general problem of global change. As was stated in Section 1, the integrated approach implies a principle of holism. Holism is the view that the whole is independent of and greater than the sum of its parts (Webster dictionary definition). In our case, 'holistic approach' is understood as the emerging of new knowledge irreducible to the sum of the knowledge of single disciplines.

The *Climatic Change* journal devoted its special issue (34, 1996) to the problems of Integrated Assessment (IA). The framework for IA presented by Rotmans and Van Asselt (1996) in their introductory article to that issue is confined by

- the multidisciplinary decision making process, and
- mutual learning of stakeholders in the process of decision making.

The principle of holism remains beyond the scope of this framework. Such IA has been known since the very beginning of human civilisation. This was confirmed by the authors who quote the Bible as the very first source of information on the IA policy practiced by agricultural managers of ancient Egypt.

In their paper in the same volume, Risbey *et al.* (1996) developed the concept of IA modelling. They noticed that the major problem of IA modelling is a paradigm conflict between biophysical and socio-economic scientists:

> Both categories of researchers use mathematical modelling as the vehicle for analysis of policy motivated questions. Natural scientists tend to use simulation methods [...]. Economists, on the other hand, rely more on optimization or optimal control approaches to find minimum global cost solutions.

The important lesson is that such methodological conflicts must be resolved in the very initial stage of the DSS design process.

2.2 'Box for mouse' as a fundamental principle of integrated approach

Minsky (1986) gives a paradox example indoctrinating the principle of holism:

> No box can hold a mouse because the box is made by nailing six boards together. No single board contains any 'containment' or 'mousetightness' property. If no single board contains such property there can't be any in six boards. Therefore, the box have no 'mousetightness' property.

Obviously, even 1000 boards will not have the 'mousetightness' quality if they were placed in a chaotic pile. The 'mousetightness' appears because the boards were nailed in a very particular shape of a rectangular prism. The same concerns apply to the multidisciplinary DSS development for integrated assessment. The question is what is the 'mousetightness' property and the 'rectangular prism' in this case? As stated above, not every DSS for integrated assessment is holistic, but the integrated (holistic) approach is always a result of integrated assessment. DSS for integrated assessment becomes holistic only if this system begets qualitatively new knowledge irreducible to the sum of knowledge provided by each component of the DSS. A meaningful consequence of this principle is that it is not possible to judge whether DSS is integrated/holistic or not at the stage of its development before the results of its application are analysed. What is the new quality knowledge that makes a DSS for an integrated assessment an integrated (holistic) DSS? Obviously, it is not a catalogue of different results obtained by each component, constituting a multidisciplinary domain of integrated assessment, even if these disciplines are integrated as separate links of one methodological chain. It is also worthwhile to note that the representation of a DSS as a single computer program is not a sufficient condition of integrated approach.

Two types of new knowledge that can be classified as qualitatively new can be highlighted. Firstly, knowledge can be defined as qualitatively new if it contradicts some commonly accepted beliefs about the system environment under integrated assessment. In other words, it disagrees with some widely spread anecdotal evidence. For example, lowland communities in Northern Thailand tend to blame highland people for overuse of water resources, causing the shortage of dry season water in the lower parts of catchments. The local administration and scientific community mostly support these allegations. It is a major source of highland-lowland conflicts in this region. Another commonly accepted point of view is that the steep slope traditional agricultural practice of hill tribe people is a major source of land degradation and deforestation in this area. To disprove this type of evidence is a sufficient condition for a DSS to deserve the title of 'an integrated/holistic system'.

Secondly, a DSS also becomes holistic if new disciplinary knowledge, unobtainable within a single component paradigm, can be obtained through the performance of this system. This aspect illustrates the distinction between integrated assessment according to Rotmans and Van Asselt (1996), quoted in the previous section, and the holistic concept of the integrated approach. The difference is that the latter allows scientists to learn more about their own discipline than is possible when this discipline is armed only with the methods from its own arsenal. A good example of this kind of result is provided by Malafant and Fordham (1995) where the water-logging processes (purely to do with hydrology) in the Riverina Basin, Australia, are predicted using the biophysical and economic scientific tools integrated in one decision support algorithm.

3. Joint venture principle

This section addresses a question emerging during any DSS design process: what kind of decisions are the designers going to support? In other words, who are the decision makers and what are their potential decisions about? The word 'stakeholder' is accepted in the DSS literature to define decision maker and so called 'stakeholder analysis' is implemented in order to answer the second part of this question. As it is closely related to the central problem considered in the present work, which is principles of scenario formulations, it is practical to review one of the basic definitions of these two terms. A clear definition of the term 'stakeholder' can be found in DID (1995):

> Stakeholders are persons, groups or institutions with interests in a project or programme (DSS development here). Primary stakeholders are those ultimately affected, either positively (beneficiaries) or negatively (for example, those involuntarily resettled[1]). Secondary stakeholders are the intermediaries in the aid delivery process. This definition of stakeholders includes both winners and losers, and those involved or excluded from decision-making processes.
> Key stakeholders are those who can significantly influence, or are important to the success of the project.

A key definition of stakeholder analysis see *ibid.*:

> Stakeholder analysis is the identification of a project's key stakeholders, an assessment of their interests, and the ways in which these interests affect project riskiness and viability. It is linked to both institutional appraisal and social analysis: drawing on the information deriving from these approaches, but also contributing to the combining of such data in a single framework. Stakeholder analysis contributes to project design through the logical framework, and by helping to identify appropriate forms of stakeholder participation.

The definition of potential DSS users as 'stakeholders' implies an analogy with a joint possession of a property. This leads us to a very important formulation of the stakeholder principle: the joint possession of intellectual property or the joint development of the DSS structure by a team of designers and potential users or their representatives is a necessary condition of the future successful application of the DSS under construction. We propose to call this a 'joint venture' principle: DSS is a joint venture where shares belong to both DSS designers and stakeholders. The results of stakeholder analysis are closely related to the very important aspects concerning the scenario plausibility and viability considered in Section 4.

4. Scenarios
4.1 Standard definitions

Most DSS designers would accept the definition given by Veeneklaas and van den Berg (1994):

> A scenario is a description of the current situation, of a possible or desirable future state as well as of the series of events that could lead from the current state of affairs to this future state.

This paper disputes such an understanding of 'scenario' because it leaves out any explanation of what these 'series of events' lead to. A meaningful question is 'What is the difference between plausible series of events and an arbitrary selected what-if constructions?'

4.2 Minsky's notion of scenario

The term 'scenario' was introduced by Marvin Minsky back in 1975 in his "A framework for representing knowledge" (Minsky, 1975). Minsky's scenario is an extension of his notion of 'frame' (*ibid.*: 212 -213). A frame is a rather

[1] There is an interesting coincidence with this DID definition and one of the IWRAM project problems addressing justification of relocation of some highland villages, practicing the steep slope agriculture, to the lowland areas.

informal notion aimed to capture expectations associated with all kinds of everyday concepts and situations, such as being in a certain kind of living room or going to a party. A frame is a network of nodes and relations. The 'top levels' of a frame represent things which are expected to be true about the supposed situation. The lower levels have many terminals ('slots') which are to be filled by specific instances or data.

Collections of related frames are linked together into frame systems. Minsky calls some frame systems 'scenarios'. Although he does not formally define what scenario is, a plausible definition can be reconstructed from his discussion (*ibid.:* 240-246). Discussing what a birthday party is, Minsky cites its dictionary definition 'a party assembled to celebrate a birthday' and rightly states that this 'lacks all the flavour of culturally required activities' (*ibid.:* 243). As is clear from what follows, 'culturally required activities' are the key words here. Thus, one could say, perhaps, that a sequence of culturally required activities associated with a culturally salient notion constitute the corresponding scenario.

One could ask what these culturally required activities could be. For example, a birthday scenario, according to Minsky, includes the following 'default assignments':

DRESS	Sunday best.
PRESENT	Must please host, must be bought and gift wrapped.
GAMES	Hide and seek. Pin tail on donkey.
DECOR	Balloons, favors, creep paper.
PARTY-MEAL	Cake, ice-cream, soda, hot dogs.
CAKE	Candles, blow-out, wish, sing birthday song.
ICE-CREAM	Standard three flavour.

So, Minsky's scenarios are constituted by 'default assignments' which are, simply speaking, a sequence of what is normally (that is, within a certain culture) supposed to be done in a situation of a kind.

Specific examples of a scenario 'inherit' its structure - a sequence of simpler frames with terminal slots which are to be filled by concrete instances (of a particular dress, particular present etc. in the case of a birthday, for example).

One can see a certain similarity between Minsky's notion of scenarios and some other constructions of social science. Minsky himself refers to Kuhn's idea of scientific paradigms (Kuhn, 1970) and Bartlett's psychological schemas (Bartlett, 1932).

4.3 Principle of scenario plausibility/viability

Minsky's frames, as well as his scenarios, are aimed to schematically represent reality, both psychological and cultural. What is a place of cultural plausibility in environmental scenario formulation? It seems that most authors in the area assume that whatever is referred to as a 'scenario' should have some cultural, economic or psychological validity or be 'plausible', reflecting, at least to some extent, the existing agricultural practice in a certain area (see, for example, Malafant and Fordham, 1995). However, it is not easy to reconstruct what procedures (heuristics or other kinds of mental processing) lead to formulating environmental scenarios considered as plausible.

4.4 Do the prototype scenarios exist?

In connection with the problem of scenario plausibility it may be of interest to examine evidence that would make possible acceptance or rejection of the following hypothesis. One could tentatively suggest that among theoretically possible combinations of parameters some constitute far more plausible scenarios than others. Some agricultural situations might have 'special' or 'prototypic' status in stakeholders' mind, being perceived as 'central' and 'culturally important' whereas others have 'peripheral' status being thought of as more or less similar to those which are 'central'. In other words, the area of agricultural situations, as many other areas of human experience, might be and probably is organised via 'prototypes', that is, special objects representing most of important features of a class, such as birds or houses or an area in a domain such as colour (Rosch, 1975).

If such prototype scenarios exist, the major task of scenario formulation would be to find out what they are and to represent them. It is also desirable to signal their special status, that is, the corresponding parameter combinations should be 'marked' somehow.

What are obvious candidates for highly plausible, or prototype, scenarios? According to Schoonenboom (1994), plausibility

> refers to the realm of prescientific knowledge, to what we, with all our experiences, can imagine as quite possible. ...We consider a future event as plausible when we have seen it before or elsewhere. So, when we mention a set of scenarios as together defining 'the plausible range of possibilities' we rest heavily on what history has taught us so far.

Thus, it is perhaps justifiable to consider plausible those scenarios which have been recurring in the past. Conceivably, the more frequently a scenario occurred in the past, the more plausible it is in stakeholders' mind. However, other than frequency of occurrence, reasons for a prototype status of a scenario remain to be investigated.

5. Scenario formulation and integrated approach

5.1 Scenario formulation and the structure of models included in DSS

As it was stated above not every what-if construction can be considered as a scenario. The major difference between a what-if construction and scenario being is that a scenario must be plausible and viable. Another requirement for scenarios formulated for DSS for integrated assessment, following from considerations expressed in Sections 4, is that scenarios for integrated DSS must promote obtaining the qualitatively new knowledge. This assumption leads us to defining integrated/holistic scenario. The structure of the scenario formulated to achieve holistic result is defined by nature of modelling tools employed by the disciplinary components of the integrated system.

5.2 Illustration of the integrated scenarios formulation

An example of how a slight alteration of the economic model structure can help to resolve a scenario formulation conflict is presented in this section. The highly simplified structure of the DSS prototype, which is being developed within the IWRAM project[2], is considered. It is assumed that this reduced prototype is constituted from two modelling modules: biophysical and economic. The biophysical module is reduced to the model of surface hydrology employing the conceptual rainfall-runoff model IHACRES (Jakeman *et al.*, 1990). This model provides monthly natural streamflow for each subcatchment using as an input the precipitation and temperature data, land use and terrain characteristics. The natural flow is used in the economic component which is organised as a linear programming (LP) optimisation procedure. The LP optimisation aims to find a set of agricultural activities, which are the areas under different crops, maximising the payoff function under several constraints defined by the resource availability (Scoccimarro *et al.*, 1999). Mathematically it falls within the class of single goal LP models.

Scenarios formulated in terms of land use areas allocated for different crops are not 'integrated' in the full sense of the word because the land use factor is subject to optimisation within the LP procedure and is considered as a DSS output rather than a scenario option. Therefore, formulation of a scenario as a selected land use option elicits the following alternative: whether to ignore the economic component of DSS or ignore the stakeholder requirement to the scenarios. Both options contradict the principles of integrated assessment formulated above. In the first case, the economic component is incapacitated. In the second case, requirements for the scenario formulation expressed by a large group of stakeholders are ignored.

Selection of a different structure of economic model would be the optimal solution to this problem. For instance, such a solution could be found by incorporating an additional optimisation procedure in the economic component. This would aim at the most efficient resource redistribution between farmers, or groups of farmers, competing for these resources within each subcatchment. This kind of optimisation falls within the sphere of competence of the game theory (Eichberger, 1993) which can be logically incorporated into the system of models constituting the economic component of the DSS under construction. In this case, a scenario, formulated as a land use option, becomes subject to economic optimisation which decides what is the optimal mutually beneficial strategy of redistribution of land, allocated for some crops within the catchment considered. This example illustrates how a simple adjustment of the structure of economic component of a DSS can help to resolve the scenario formulation conflict.

[2] The Integrated Water Resource Assessment and Management (IWRAM) project is aimed to construct DSS for sustainable development of highland rural catchments in the Upper Ping Basin, Northern Thailand.

6. Summary remarks

Some basic definitions and principles of scenario formulation for DSS for integrated assessment were considered in the present work. An important outcome of the paper concerns a terminological difference between 'DSS for integrated assessment' and 'integrated (holistic) DSS'. It is concluded that the latter term can be used only for those DSS for integrated assessment which provide integrated/holistic outputs. In other words, the question whether a DSS is holistic is subject to results (or in other words, new knowledge) obtained by using this system.

The scenario formulation process, being the crucial part of the integrated approach, should be based on the principle of 'joint venture'. This means that scenarios should aim at reflecting stakeholders' experience and style of reasoning as well as the DSS designers' purposes. Presumably, scenarios should be plausible and viable from stakeholders' point of view. What makes a plausible scenario remains to be investigated. However, it seems that cultural factors, such as stakeholders' experience, play a major role.

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