Multi-Layer Decision Support Model for Value and Cost Analysis of IT Solutions: Hierarchical Approach

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ABSTRACT

The article presents mechanisms of value and cost evaluation that accompany decision making processes in hierarchical systems, while performing complex IT projects. Every designing operation, performed in set deterministic or probabilistic conditions, is a decision making activity (selection activity) that initiates expected value and costs that occur with it. AIDA method has been selected as a starting point of the model's structure. The scope of applying of this method has been extended to modeling of decision making process in a hierarchically structured organization. Deliberations have been limited to the deterministic model with the assumption that selection of every decision, from the finite set of variants, is evaluated in two categories: V – expected benefits and C – incurred costs. Making a decision "agreed" in many layers is crucial for hierarchic structures. It is necessary to assure its global realization ability and maximize the expected value in relation with estimated costs. Deliberations are exemplified with a decision making process which accompanies launching a new IT project with cost-based limitations.

INTRODUCTION

The use of multilayer decision support model for value and cost analysis of major IT projects results from the analogy to the manner in which this kind of decisions are prepared and undertaken. The most common practice, present in many enterprises – especially financial institutions and insurance companies, considers two levels of decision making about IT project and their complex structure: strategic decisions level (s) and tactical decisions level (t).

Strategic decisions level considers the following aspects:

(0s) business strategy of the enterprise,
(1s) expected benefits,
(2s) incurred costs,
(3s) available technology,
(4s) reliable suppliers and contractors,
(5s) guaranteed safety.

Tactical decisions level includes the following aspects:

(0t) IT introduction strategy,
(1t) IT introduction program,
(2t) IT projects management,
(3t) scope and cost of IT audit,
(4t) scope and cost of outsourcing,
(5t) license purchase cost,
(6t) infrastructure purchase cost,
(7t) implementation cost.

Both presented decision levels permeate each other creating a network of cause-and-effect relationships. Their solution cannot be unambiguous due to indetermination or random character of macroeconomic (e.g. turbulent market) or technological (e.g. innovations in the areas of nano- and biotechnology) phenomena.

Routine decision making processes in hierarchical systems realization are accompanied by many phenomena which should be identified and managed. In case of unique ventures like IT projects to its managing, in general meaning, specific IT solutions are used. These solutions support: planning and organizing activities, budgeting, technical and logistic operations as well as controlling and corrective actions.

Project management occurs when the variant that has been chosen to realization is revealed from all of its more or less documented variants.

This article deals with the stage of creating and designing an IT project as well as estimating its economical effects for the organization that implements the project.

AIDA* method was selected as a starting point for the creation of the whole model. Its scope of use and implementation was expanded to decision making process modeling in a hierarchically structured organization.

According to the AIDA technique, decision making process is a process of preparing *alternative variants of decision* (AVD) and a process of selecting one of these variants for realization. Determining inwardly alternative *decision areas* (D_i) that consist of *elementary decisions* (d_{ji}) and indicating *mutually contradictory elementary decisions* that are included in different decision areas - is performed during this process.

In order to generate AVD, so called apexes of tree of results are formed. This process is accompanied by estimation of the V value growth and estimation of cost C connected with this project for the organization that implements the project (see Fig. 1).

Successive steps leading to a multilayer decision making model are presented in the following fragments of the article: *Decision making process – basic assumptions; AIDA method; AIDA method in solving a single-layer model; Estimating value and costs in single-layer model; Construction of a multilayer model; AIDA method in solving a multilayer model and Estimating value and costs in multilayer model.*

DECISION MAKING PROCESS: BASIC ASSUMPTIONS

Decision making process is a *alternative variants of decision* (AVD) preparation process as well as selection of one of the variants for further realization.

Preparing the AVD consists of determining relevant *decision areas* (D_i), for a set decision problem, which will provide partials of the *elementary decisions* (d_{ji}) that are not contradictory in constructed AVD model.

This part of the article deals with a single-layer decision-making process model in a strictly theoretical (general) manner.

In order to avoid terminological misapprehensions the meaning of keywords used in the article is presented below:

- *Decision Problem* (DP) – set of decision-making areas that specify particular areas of decision making process,
- *elementary decision* (d_{ji}) – making this decision implicates elaborating D_i and selecting one suitable d_{ji},
- *Variant of Decision* (VD) – sorted n elements indicated for realization, created from single elements (elementary decisions d_{ji}) that belong to sets of elements alternative to each other, namely decision areas (D_i),

- *Decision Preparation Process* (DPP) – process of elaborating D_i as well as AVD generation process connected with indicating *Variants of Decisions* (VDs) that are the most beneficial for further realization,
- *Decision Space* (DS) – collection of all non-contradictory AVDs,
- *Hierarchical system* – from the mathematical point of view it is a partly sorted structure that consist of: elementary decisions, decisions areas and variants of decisoins.

Example of a single-layer DP model in the form of graph is presented in Fig.1. D_1, D_2, D_3 symbols stand for decision making spaces; $d_{11,}$ $d_{21,\ldots,}$ d_{33} symbols stand for elementary decisions.

Capital letters V, C mark the proportional share of a particular decision area in organizations value growth and IT project realization costs. Small letters v, c stand for proportional share of particular elementary decision in proportion to remaining elementary decisions from a considered decision area in organizations value growth and IT project realization costs.

Creation of DP graph model starts from eliminating these D_i, which collections include only one elementary decision and eliminating repetitive elementary decisions.

Apexes of the graph that correspond with elements of one decision making area are connected with lines (dotted line). Lines symbolize the fact that connected elements are alternative. Due to aprioristic collisions of some of the elements, that belong to different decision areas, suitable apexes of the marked with these elements are connected as well (continuous line).

AIDA METHOD

Designing decisions in single-layer model is performed by the activity of defining DP as a decisoin areas collection and defining relationships between elements present in these areas (see Fig. 1) without the necessity to undertake separate analysis of morphological relations between the elements of each collection.

AIDA method elaborated by J. Luckman distinguishes from other well-known methods of morphological analysis (morphological box, randomization with the use of sets, Moles methods) with high efficiency and relative simplicity.[1, 2]

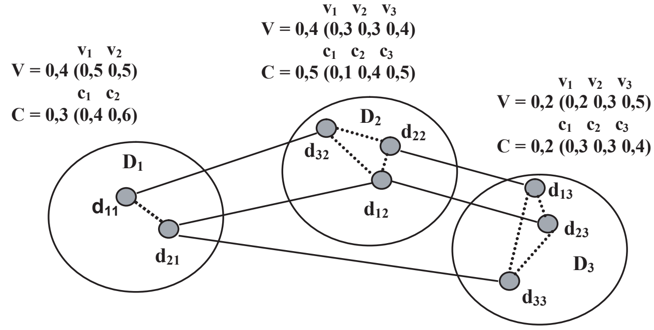
Initial stage of performance of this technique is specifying decision areas recorded as, so called, *Formulating Sets* (FS). Every D_i has homological properties that is its elements in specific variants of the solution can be exchanged by others. Cartesian product of all decision areas determines the *Decision Space* (DS) of particular *Decision Problem* (DP).[3]

AIDA method can be used for two different goals:

- to generate admissible elements of the decision area,
- to generate discrete stages trajectory of solving DP in the DS.

First case presents decision areas decomposition process that leads to the form of AVDs, from which the final result is selected. In second case AIDA is used to generate "quick" variants of decision that are interpreted as discrete stages of *Decision Preperation Process* (DPP) in the DS.

Figure 1. Example of a single-layer DP graph model



Process of generating elements and trajectories of the DS should be evaluated both in quantitive and qualitative way. The most promising use of AIDA method is in case of major and complex decision areas - that is every time when the moment of making a decision should be preceded with the stage of generating all or almost all VDs.

In some of the practical uses it is necessary to take into consideration the limited available time to take particular decision and costs connected with elaborating DPP – in this aspect the AIDA method can be used to prepare a limited number of decision making variants which should include an optimal variant (it concerns especially the tasks of steering in conditions with system parameters of great dynamics or searching for results variants in conditions that include a considerable number of probabilistic limitations). Second collection of AIDA method uses can be related directly to realization of complex IT projects, which budgets usually account for millions of dollars and the benefits and costs of implementation occur simultaneously with the time of managing the project.

AIDA METHOD IN SOLVING A SINGLE-LAYER MODEL

Any decision area (represented by so called formulating set) will be marked as $\mathbf{D_i}$, and $\mathbf{d_{ji}}$ stands for a j-th elementary decision of this area.

Decision space (DS) of morphological analysis is signified as $\mathbf{D_1 \times D_2 \times \ldots \times D_m}$ or as a set of vectors $\{<\mathbf{d_{j1}, d_{j2}, \ldots, d_{jm}}>\}$, with the assumption that $\mathbf{d_{ji}} \in \mathbf{D_i}$ and that the power of any decision making area $|\mathbf{D_i}|$ is a limited value.

The solution of a decision problem (DP) is the defined set of decision areas $\mathbf{D_i}$ and generated and evaluated correct vectors $<\mathbf{d_{j1}, d_{j2}, \ldots, d_{jm}}>$ at a decision tree (see Fig. 2).

The essence of AIDA method is to perform the four following steps:

[a] determine inwardly alternative decision areas that describe the set problem,
[b] determine contradictory elementary decisions that are in different decision making areas,
[c] generating and eliminating these VDs of the decision areas which include contradictory pairs of elementary decisions,
[d] sorting and analyzing remaining VDs.

The procedure of generating VDs is based on the decomposition of the DP graph model. Decomposition is based on systematic separating inwardly stable variants of formulating set's. Inwardly stable set is the one which fulfills two conditions:

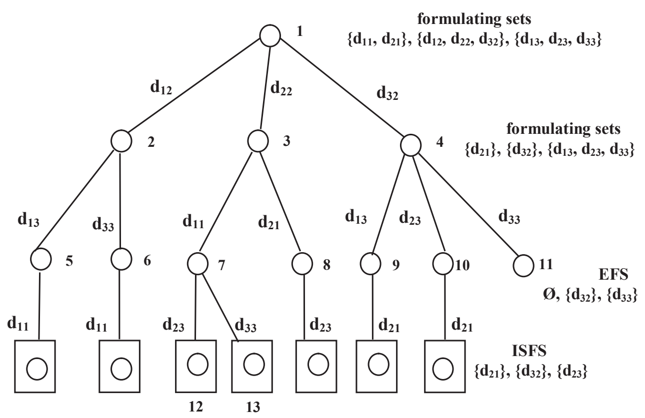
- It consists of as many decision making elements as there are decision areas,
- It does not include pairs of elementary decisions that eliminate each other.

For example in $\mathbf{D_1}$, $\mathbf{D_2}$, $\mathbf{D_3}$ decision areas (see Fig. 1) the following sets are inwardly stable: $\{\mathbf{d_{11}, d_{22}, d_{33}}\}$, $\{\mathbf{d_{11}, d_{12}, d_{13}}\}$, $\{\mathbf{d_{21}, d_{32}, d_{23}}\}$.

Generating VDs has the following agenda:

(a) the power (number of elements) of each formulating set is specified,

Figure 2. Example of tree of results for single-layer model



(b) formulating sets are sorted according to the decreasing value of their power,
(c) formulating sets of elementary decisions that are included in all decision areas are divided into as many groups of sets as the value of largest formulating set's power,
(d) apexes of the tree of results are formulated together with the lines growing out of them, which have specific groups of formulating sets attributed to them.

Realization of operations (a) to (d) is exemplified at the tree of results in Fig. 2.

It is necessary to take into consideration that while creating formulating sets for newly created apexes of lower levels of the tree, there cannot be any elementary decisions that are alternative to these elementary decisions towards which the formulating sets division takes place. If, due to the division, the power of one of the formulating set becomes equal to 0 (the set is empty) – it indicates that this particular group of formulating sets is eliminated from the process of division and marked as EFS (Eliminated Formulating Sets). If the power of all formulating sets in a particular group equals 1 – this group becomes the variant of inwardly stable set of decisions and is marked as ISFS (Inwardly Stable Formulating Set). Remaining formulating sets are sorted decreasingly due to the value of their power and the realization of (c) and (d) operations is triggered again.[4, 5]

The operations (a) - (d) are repeated until the groups of formulating sets will consist only of EFS and ISFS elements. Groups marked as ISFS are the collection of allowable results that is the set of all possible VDs, which do not include pairs of alternative elementary decisions.

In the tree of results (see Fig. 2), ISFS that reflect the lowest level of apexes are marked with a frame.

The gained ISFS results are:

$\{d_{11}, d_{22}, d_{33}\}$, $\{d_{11}, d_{12}, d_{13}\}$, $\{d_{21}, d_{32}, d_{23}\}$, $\{d_{11}, d_{12}, d_{33}\}$,
$\{d_{11}, d_{22}, d_{23}\}$, $\{d_{21}, d_{22}, d_{23}\}$, $\{d_{21}, d_{32}, d_{13}\}$

ESTIMATING VALUE AND COST IN A SINGLE-LAYER MODEL

Process of generating formulating sets for every apex of tree of results (see Fig. 2) is accompanied by estimating of the value growth of the organization implementing the IT project together with estimation of the cost of project's realization (see Fig. 1).

In order for the estimation to be possible an assumption is necessary: every $\mathbf{D}_i$ percentage share, on the scale of **[0..1] X 100**, is set both in **V** value and costs **C** – with additional assumption that sum of each of these shares in all decision areas equals **100**.

For the example presented at Fig. 1 sums of all shares are as following:

$$V_{D1} + V_{D2} + V_{D3} = 100$$
$$C_{D1} + C_{D2} + C_{D3} = 100$$

V-C characteristics for particular $\mathbf{d}_{ji}$ in every $\mathbf{D}_i$ are determined similarly:

$$v_{d11} + v_{d21} = 100 \qquad c_{d11} + c_{d21} = 100$$
$$v_{d12} + v_{d22} + v_{d32} = 100 \qquad c_{d12} + c_{d22} + v_{d32} = 100$$
$$v_{d13} + v_{d23} + v_{d33} = 100 \qquad c_{d13} + c_{d23} + v_{d33} = 100$$

For each group of formulating sets connected with the developed tree apex with **x** index, **max** and **min** of expected percentage value ($\mathbf{V}_x^{\mathbf{max}}$, $\mathbf{V}_x^{\mathbf{min}}$) and expected percentage cost ($\mathbf{C}_x^{\mathbf{max}}$, $\mathbf{C}_x^{\mathbf{min}}$) are determined. Results of particular calculations for the presented example at Fig. 1 are collected in Tab. 1.

Analysis of the tree of results presented in Fig. 3 indicates that three of the best relations between cost of IT project realization and increase of organization's value can be achieved in a form of a result marked as No 5, No 6 and No 13.

Upper and lower **V–C** limitations can be used in automatic model revision in models with hundreds or thousands elements. In such case there are aprioric limitations for allowable scope of diversity separately for parameter **V** and **C**. V-trees and C-trees of results are constructed; the best **V/C** solutions are present in a mutual part of both trees.

Reached solution (apex) No 6 with **V/C = 1,68** is present in mutual part of both trees where **V ≥ 42** and **C ≤ 25**.

CONSTRUCTION OF A MULTILAYER MODEL

In hierarchical systems the decisions are made on several layers according to the situation present in adjacent layers. Process of designing and taking the decision is dependent on the character of the organization – although decisions in higher layers are always based on the decisions in lower layers – and symmetrically: decisions in lower layers are based on decisions in higher layers. Therefore we can observe two interdependent streams of decision preparation.

Fig. 4 illustrates mutual placement of decision making problems at higher (strategic), intermediate (tactical) and operational layers. It is easy to observe that decision area (that includes elementary decisions) at a higher layer becomes a decision problem for the layer placed beneath it.

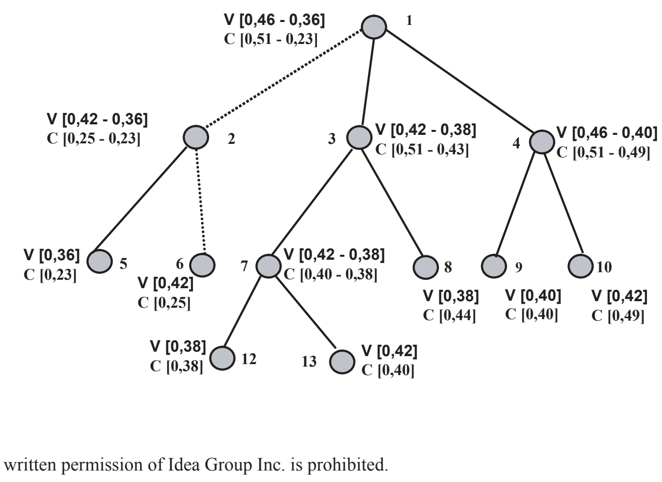
Structure of a multilayer DP graph model (see Fig. 4) is based on the following rules:

- each defined decision area placed at a certain DP layer or at a adjacent layer has all possible elementary decisions determined,
- for a collection of elementary decisions that belong to a decision area of higher layer a DP of lower layer has to be determined, its solutions in a form of alternative variants of decision (AVD) should unambiguously relate to particular elemetary decisions (see Fig. 4, elementary decisions No 5, No 6, No 13 and relevant AVDs as DP solutions in a tactical layer),

Table 1. Example of proportional value estimation for formulating sets

No	Group of formulating sets	next No	V^{max}	V^{min}	C^{max}	C^{min}
1	$\{d_{11}, d_{21}\}, \{d_{12}, d_{22}, d_{32}\}, \{d_{13}, d_{23}, d_{33}\}$	2,3,4	0,46	0,36	0,51	0,23
2	$\{d_{11}\}, \{d_{12}\}, \{d_{13}, d_{33}\}$	5,6	0,42	0,36	0,25	0,23
3	$\{d_{11}, d_{21}\}, \{d_{22}\}, \{d_{23}, d_{33}\}$	7,8	0,42	0,38	0,51	0,43
4	$\{d_{21}\}, \{d_{32}\}, \{d_{13}, d_{23}, d_{33}\}$	9,10,11	0,46	0,40	0,51	0,49
5	$\{d_{11}\}, \{d_{12}\}, \{d_{13}\}$	ISFS	0,36	0,36	0,23	0,23
6	$\{d_{11}\}, \{d_{12}\}, \{d_{33}\}$	ISFS	042	0,42	0,25	0,25
7	$\{d_{11}\}, \{d_{22}\}, \{d_{23}, d_{33}\}$	12,13	0,42	0,38	0,40	0,38
8	$\{d_{21}\}, \{d_{22}\}, \{d_{23}\}$	ISFS	0,38	0,38	0,44	0,44
9	$\{d_{21}\}, \{d_{32}\}, \{d_{13}\}$	ISFS	0,40	0,40	0,49	0,49
10	$\{d_{21}\}, \{d_{32}\}, \{d_{23}\}$	ISFS	0,42	0,42	0,49	0,49
11	Ø, $\{d_{32}\}, \{d_{33}\}$	EFS	-	-	-	-
12	$\{d_{11}\}, \{d_{22}\}, \{d_{23}\}$	ISFS	0,38	0,38	0,38	0,38
13	$\{d_{11}\}, \{d_{22}\}, \{d_{33}\}$	ISFS	0,42	0,42	0,40	0,40

Figure 3. Example of estimating solutions for a single-layer model



- partial overlapping of separate DPs in the form of mutual decision areas is possible (one ecision area belongs to one or more different decision problems),
- decision areas placed on operational layers should include only aprioric elementary decisions which cannot be the result of searching AVDs for even more detailed decision areas,
- number of elementary decisions in particular decision area should be limited to the smallest possible number of the most beneficial solutions according to **V/C** ratio – which means significant value growth in proportion with smallest cost growth,
- values of **V** and **C** in the aspect of cost for any decision area of particular higher layer should be the sum of $\mathbf{V_s}$ and $\mathbf{C_s}$ values for all $\mathbf{s \in S}$, where $|\mathbf{S}|$ is a number of decision areas partials of a layer that is directly beneath,
- decision-making problems decomposition should be limited to the smallest possible number of layers.

Example

Global expected value of organizations value growth is equal to **V = 300 mln $**, project cost equals approximately **C = 80 mln $**. Decision area including elementary decisions No 5, No 6 and No 13 is placed in the strategic layer (see Fig. 4) and is responsible for **30%** of **V** growth (**90 mln $**) and **40%** of **C** cost (**32 mln $**). Decision areas $\mathbf{D_1}$, $\mathbf{D_2}$, $\mathbf{D_3}$ placed in the tactical layer are responsible for cost-based and percentage share according to values presented in Tab. 2.

Real cost of the IT project is dependent on elementary decisions undertaken on each decision making layers. Real evaluation of organizations value growth will be verified by the market.

ESTIMATING VALUE AND COST IN A MULTILAYER MODEL

Estimating the market value growth created due to engagement of an enterprise in implementation of a new IT project is an endeavor of high responsibility. Commonly encountered issue of significantly exceeding the budget and not being able to meet deadlines for projects of this type has been statistically proved.

Table 2. Example of V-C relation in decision-making layers

	D_1	D_2	D_3	Σ
V [%]	40	40	20	100
C [%]	30	50	20	100
V [mln $]	36,0	36,0	18,0	90,0
C [mln $]	9,6	16,0	6,4	32,0

Figure 4. Multilayer DP graph model (includes the Fig. 1 model with results No 5, No 6 i No 13 at a strategic layer)

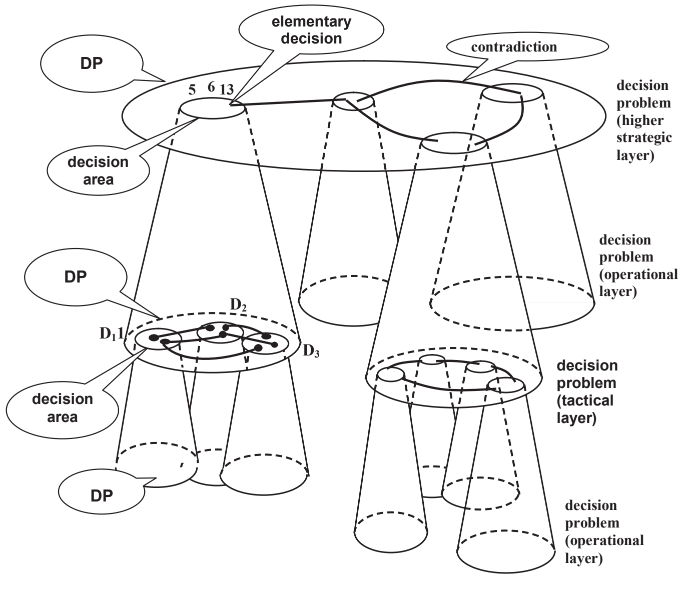


Table 3. Example of three decision variants in tactical layer

No	Groups of formulating sets	Share of AVD in D_i [mln $]			ΣV / ΣC	V/C
		D_1	D_2	D_3		
5	$\{d_{11}\}, \{d_{12}\}, \{d_{13}\}$	18,00	10,80	3,60	32,40	4,54
		3,84	1,60	1,92	7,36	
6	$\{d_{11}\}, \{d_{12}\}, \{d_{33}\}$	18,00	10,80	9,00	37,80	4,73
		3,84	1,60	2,56	8,00	
13	$\{d_{11}\}, \{d_{22}\}, \{d_{33}\}$	18,00	10,80	9,00	37,80	2,95
		3,84	6,40	2,56	12,80	

On the basis of prior considerations the part of alternative variants of decision (AVD) with the No 5, No 6 and No 13 in particular decision areas has been converted as well as the value of **V/C** relation has been calculated.

The most profitable result has not been changed in proportion to the proportional share and, what is especially intriguing, it proved to be better than a simple reference of expected global organizations value growth (**V = 300 mln $**) to project cost (**C = 80 mln $**), which in this case equals **V/C = 3,75** (see Tab. 3). This result can indicate that decisions reached and estimated in parallel on two layers can be more precise than in a single-layer model.

Presented argumentation has some simplifications that were necessary to separate two layers (strategic and tactical) and prove that calculations elaborated in tactical layer are more precise than simple reference of global **V/C** values in strategic layer in case of the model presented in Fig. 4 .

SUMMARY

Presented approach towards hierarchic decision-making processes modeling in IT solutions has been corroborated with many test-runs performed on IT tools prototypes.[6, 7]

The article deals with an attempt to introduce weighted evaluations of economic type into a hierarchical model, which are assigned to decomposed decision making problems, layers of decisions and areas and particular elements of decisions. It is illustrated with computational examples – however, the Author is aware of the fact, that not all of the issues could be presented in a sufficient level of detail due to the complexity of this problems and editorial limitations.

Main limitation of the presented model is an assumption of model's static nature and lack of probabilistic characteristics – although the latter are being tried to change with the approximation of "percentage share/effect" of particular decision in the whole solution. Another inexactitude would be omitting the influence of synergetic relations at the value and costs. These kind of relations occur naturally due to the correlation between particular decision elements.

Author is aware of listed imperfections of the model and will be gradually eliminating them in further research on the essence and economical characteristics of highly structured decision making processes.

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ENDNOTES

* Analysis of Interconnected Decision Areas.

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