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QUALITATIVE EVALUATION OF KNOWLEDGE BASED MODEL OF PROJECT TIME-COST AS DECISION MAKING SUPPORT

Abstract. *An integral part of effective project management is the knowledge management. Knowledge analyses are based on deep information(equations)or shallow information (verbal description). The paper presents a quantitative evaluation of qualitative knowledge model. Qualitative quantifications are based on three words (increasing, constant, decreasing).Any qualitative model M has a discrete set of qualitative scenarios S. An algorithm is used to generate all possible transitions O among the set of S. A transitional graph T has as nodes scenarios S and as arcs transitions O. Any behaviour of the model M can be described by a sequence of scenarios.A tree R, which is sub-graph of the T graph and can be taken for any qualitative forecasting, is used to evaluate probabilities of different branches of the tree. The presented evaluation provides new knowledge analysis and its main advantage is that no numerical values are needed. The qualitative model shows a seven-dimensional project management problem.*

Keywords**:** *equation less model, quantitative evaluation, qualitative tree, decision support, knowledge management, project management.*

JEL Classification: C63, E60

1. Introduction

An integral part of effective management is the work with knowledge. Therefore, knowledge management plays a key role in different parts of management, e.g. business, industrial. Recently are solved many management problems with the use of project management. The project management is a very complicated process. Definition of a successful project is various and it depends on many factors, see e.g.(Jugdev and Muller, 2005; Serrador and Pinto, 2015). The metrics, such as a scope, costs and purpose of a project, customer satisfaction, etc., see (Joslin and Müller, 2015), are usually considered as the criteria of project success.

The relevant and quality information / knowledge plays a key role in project success. The knowledge is the build stone of the project management in each project life cycle. By practical application of project management is the most knowledge formed gradual work on project usually. But into the planning and management processes must be implemented immediately. Therefore, knowledge management plays the main role in the project management.

Important phase of project management is cost analysis of a project. There are many articles that deal with the identification of a knowledge related to the time cost analysis of the project. Time, cost, and quality are three important conflicting factors. These must be optimally balanced during the planning and management of projects. We want execute the project as soon as possible with minimal total cost and not exceed available resources, e.g. humans, materials, etc. This optimization problem can be solved using either widely used methods, such as CPM/COST, MPM/COST, PERT/COST (Sears, 1981)or methods based on the knowledge management.CPM/COST method is an extension of the CPM (Critical Path Method) method about cost analysis. This method deals with optimizing the cost and time by deterministic evaluation of activities durations and costs.(Sears, 1981) PERT/COST method is an extension of the PERT (Program Evaluation and Review Technique) method about cost analysis. This method deals with optimizing the cost and time by stochastic evaluation of activities durations and costs.

The research by the authors Mohadem and Celik (2002)presents an integrated knowledge based system for construction cost estimating and scheduling. The knowledge based system supports an automated alternative design analysis with on line schematic drawing, material selection, crew selection and productivity analysis(Deng, 1993).The article by the authors Tran, Cheng and Cao presents a hybrid multiple objective evolutionary algorithm based on the knowledge base system of bee colonies(Tran, Cheng and Cao, 2015).The authors Kosztyan, Bencsik and Pota present an algorithm which an optimal resource allocation with minimal total cost of project could be determined. This algorithm also handles some knowledge of the human resources(Kosztyan, Bencsik and Pota, 2007).

The key problem of above mentioned methods is a serious shortage of information (Dohnal, 1991; Babu and Krishna, 2013).Quantitative statistical analysis has developed some feedbacks which signal danger of information shortages, see e.g. (Aznarte et al., 2011). If information shortages signals are reliable then just qualitative results can be reached. However, qualitative analysis can be very useful if further conventional statistical analysis is feasible and interesting. Objective and subjective methods must be synthesized to gain the obvious benefits of objective precision and semi-subjective common sense abilities, see e.g. (Dai, Han and Dai, 2014). However, such some knowledge is heavily subjective, difficult to measure /

observe and therefore poorly known systems are studied. A knowledge acquisition process is needed to extract the relevant knowledge from the numerical series(Deng, 1993). Such acquisition processes are able to use a wide range of techniques, e.g. automatic induction of rule based systems (Žabkar et al., 2013).

Deep knowledge items are such laws which reflect undisputed elements of the corresponding theory. For example, the law of gravity has no exceptions. This is a typical feature of some deep knowledge item.

However, such soft sciences, e.g. management, economics and sociology, are just very rarely based on deep knowledge items. A shallow knowledge item is usually a heuristic or a result of observations and has usually lots of exceptions, see e.g. (Orrell and Fernandez, 2010).

A lot of shallow knowledge items are available just as verbal descriptions based on trends, *decreasing, constant, increasing*(Yanet al., 2013). For example: *If the project duration is shortening then the personal costs are increasing.*Typical examples of such pair wise trend relations are given in the Figure1.

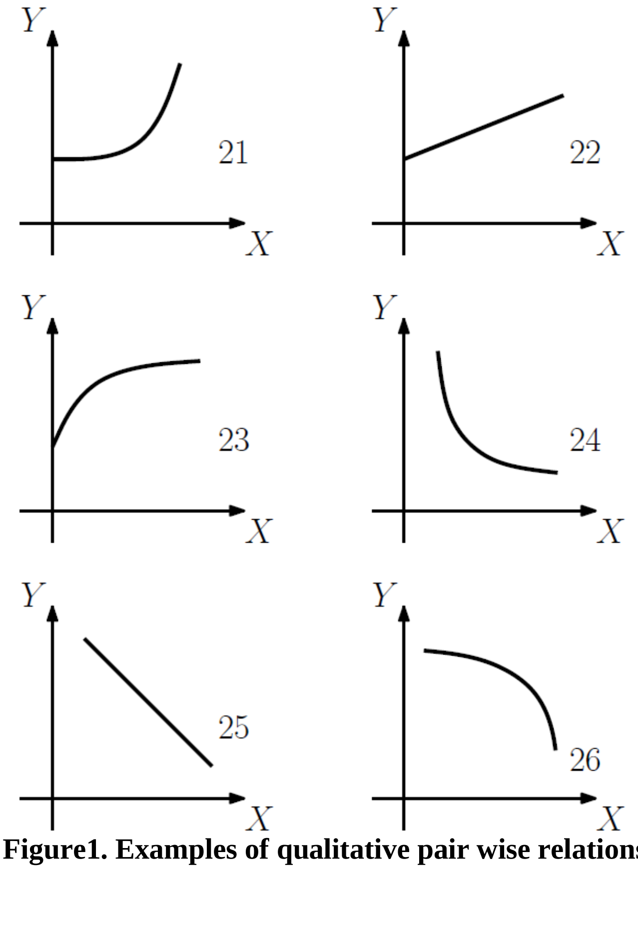

Figure1. Examples of qualitative pair wise relations

The pair wise relations in the Figure1 are trend relations. It means that nothing is quantified. For example, the relation No. 21 indicates that:

- The relation is increasing, the first derivative is positive.
- There is an ”increasing’’ relationship between *Y* and *X*, the second derivative is therefore positive.
- If *X* = 0 then *Y* = positive value.

Decision making using a decision trees is a powerful method in data mining(Bukchin and Rozenes, 2011). However, real world applications of decision trees exhibit uncertainty through missing and / or imprecise data, see e.g.(Zheng and Zhu, 2015). To deal with these uncertainties decision trees based on sets of scenarios is used.

2. Qualitative Models

Generally, the diversity of techniques and methods employed in Project management can be classified into qualitative and quantitative, based on the nature of the procedures they employ(Takey and de Carvalho, 2015; Bentahar, 2015).The qualitative methods in this paper use qualitative variables and are based on four qualitative values, see e.g. (Žabkar et al., 2013):

Positive[+], *Zero*[0], *Negative*[–] and *Any value* [*]. (1)

There are different qualitative models

$$\mathrm{M}(\mathrm{X}) = 0\,. \qquad (2)$$

The qualitative model can be represented by a set of differential equations, for details see (Vicha and Dohnal, 2008a).The solution of the model (2) is specified if all its *n* qualitative variables

$$X_1, X_2, \ldots, X_n \qquad (3)$$

are described by qualitative triplets

$$(X_i, DX_i, DDX_i), \qquad (4)$$

where *DX* and *DDX* are the first qualitative and second qualitative time derivatives, for details see(Dohnal, 1991).

The third and higher derivatives can be taken into consideration as well. However, they are often unknown. This is the reason why just the second derivatives *DDX* are used in this paper.

A set B of *m* qualitative *n*-dimensional scenarios is a solution of the model (2). It is described by the following set of triplets:

$$\mathrm{B} \equiv \left[(X_1, DX_1, DDX_1), (X_2, DX_2, DDX_2), \ldots, (X_n, DX_n, DDX_n)\right]_j \qquad (5)$$

$$j = 1, 2, \ldots, m\,.$$

Rather often it is a priory known that some variables are always positive. A traditional example is a temperature given in Kelvin degrees. Moreover, some relations are so poorly known that the second derivative is not known. Therefore, the triplet (4) is more specific:

$(+, DX, *)$, see (1). (6)

Realistic qualitative models can have hundreds of scenarios, see e.g. (Vicha and Dohnal, 2008a).

A qualitative shallow model, studied in this paper, is a set of *w* pair wise relations, see theFigure1:

$P_v(X_i, X_j),\ v = 1, 2, \ldots, w.$ (7)

This set of relations can be solved to evaluate all such scenarios (5) which satisfy the model (7). This paper does not study algorithms which are used to solving qualitative models, for details, see e.g. (Vicha and Dohnal, 2008b).For example, the following set of relations is studied:

	Shape	*X*	*Y*	
1	21 (see the Figure1)	X_1	X_2	(8)
2	25 (see the Figure1)	X_3	X_2	

The model (8) is solved and 13 three-dimensional scenarios (9) are obtained:

	X_1	X_2	X_3	
1	+ + +	+ + +	+ – –	
2	+ + 0	+ + +	+ – –	
3	+ + –	+ + +	+ – –	
4	+ + –	+ + 0	+ – 0	
5	+ + –	+ + –	+ – +	
6	+ 0 –	+ 0 –	+ 0 +	
7	+ 0 0	+ 0 0	+ 0 0	(9)
8	+ 0 +	+ 0 +	+ 0 –	
9	+ – +	+ – +	+ + –	
10	+ – 0	+ – +	+ + –	
11	+ – –	+ – +	+ + –	
12	+ – –	+ – 0	+ + 0	
13	+ – –	+ – –	+ + +	

3. Transitional Graph

A complete set of all possible one-dimensional transitions is given in the Tab. 1

The third line of the Table1 indicates that it is possible to transfer the triplet (+ + –) into the triplet (+ 0 –). The Table1 is not a dogma. It could be modified on ad hoc basis. The only requirement is that the transitions must satisfy a common-sense reasoning of a user.

A transitional graph T is an oriented graph. Its nodes are the set of scenarios S and oriented arcs are the transitions O:

$$\mathrm{T}(\mathrm{S},\mathrm{O}). \tag{10}$$

The set of *n*-dimensional transitions O can be easily generated by the corresponding set of scenarios S using the Table1. All *n* one-dimensional transitions must satisfy the Table1 if *n*-dimensional scenarios are studied.

Table1. A list of all one-dimensional transitions

	From	To	Or	Or	Or	Or	Or	Or
1	+ + +	+ + 0						
2	+ + 0	+ + +	+ + –					
3	+ + –	+ + 0	+ 0 –	+ 0 0				
4	+ 0 +	+ + +						
5	+ 0 0	+ + +	+ – –					
6	+ 0 –	+ – –						
7	+ – +	+ – 0	+ 0 +	+ 0 0	0 – +	0 0 +	0 0 0	0 – 0
8	+ – 0	+ – +	+ – –	0 – 0				
9	+ – –	+ – 0	0 – –	0 – 0				
10	0 + +	+ + 0	+ + –	+ + +				
11	0 + 0	+ + 0	+ + –	+ + +				
12	0 + –	+ + –						
13	0 0 +	+ + +						
14	0 0 0	+ + +	– – –					
15	0 0 –	– – –						
16	0 – +	– – +						
17	0 – 0	– – 0	– – +	– – –				
18	0 – –	– – 0	– – +	– – –				
19	– + +	– + 0	0 + +	0 + 0				
20	– + 0	– + –	– + +	0 + 0				
21	– + –	– + 0	– 0 –	– 0 0	0 + –	0 0 –	0 0 0	0+0
22	– 0 +	– + +						
23	– 0 0	– + +	– – –					
24	– 0 –	– – –						
25	– – +	– – 0	– 0 +	– 0 0				
26	– – 0	– – –	– – +					
27	– – –	– – 0						

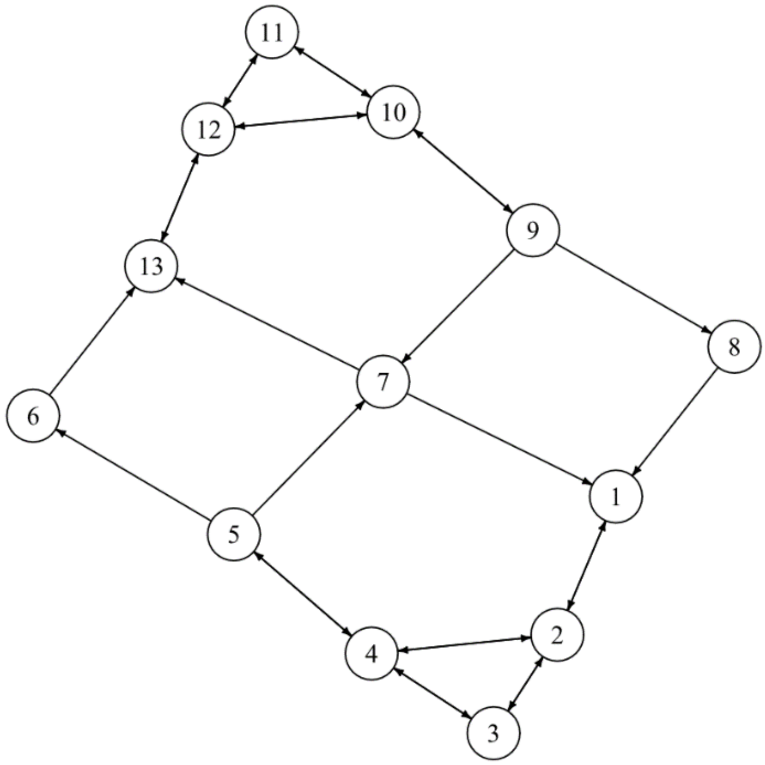

Figure2. Transitional graph of the scenarios(9)

The graph T(10) can have loops and therefore a path can pass through the loop infinitely many times, see e.g. the scenarios 2, 3 and 4 in theFigure2. A qualitative tree R is a studied sub-graph of the transitional graph T and it has no loop by definition.

Let the scenario No. *i* be a root scenario of a tree. A decision maker must choose such set of terminal scenarios ST_i which, uniquely specify a tree R which has the scenario S_i as its root and ST_i as its set of terminal scenarios:

$$R(S_i, ST_i). \tag{11}$$

4. Illustrative Example

A tutorial interpretation of the variables used in the model (8) is:

X_1 – Project duration

X_2 – Direct personal costs (12)

X_3 – Direct material costs

Let the scenario No. 12, see the Figure2, be the current situation, i.e. S_{12} is the root (11). The chosen set of terminal scenarios ST_{12} is:

$$ST_{12} \equiv \{S_7, S_{11}, S_{13}\}, \tag{13}$$

The tree R (S_{12}, ST_{12}) (11) is given in the Figure3.

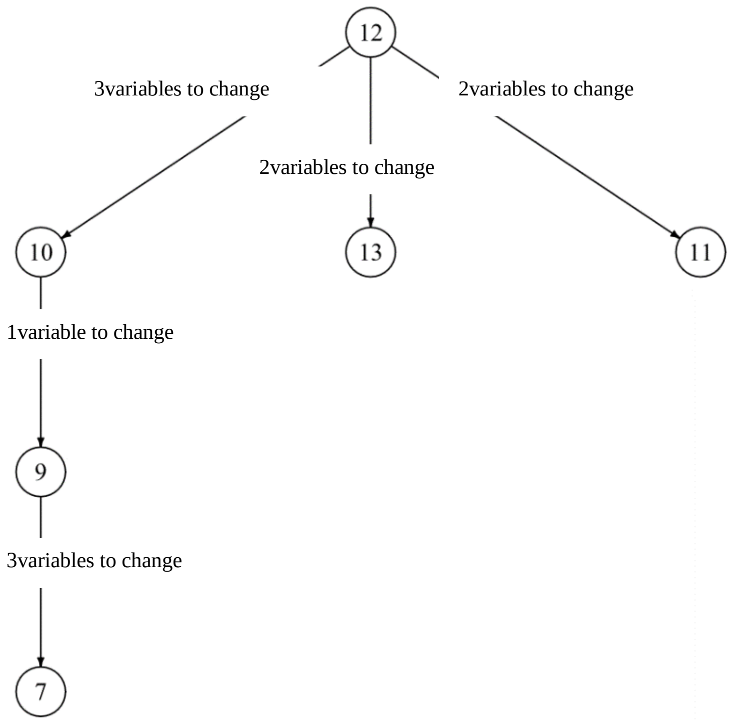

Figure3. Qualitative tree

Each node of the tree, see the Figure3, has its description / characteristic, e.g. the scenario No. 7 is the terminal scenario. Its project duration is positive (+ 0 0), see (9), (12). The list of all possible transfers from the scenario No. 12 is, see the Figure2and the Figure3:

12→10	(a)	
12→11	(b)	(14)
12→13	(c)	

For example, the transition (c) is, see (9):

	X_1	X_2	X_3		
12	+ – –	+ – 0	++0	From	(15)
13	+ – –	+ – –	++ +	To	

The only further step is to return to the scenario No. 12, see the Figure2. However, if the direct material cost is increased to (+++) then the move to the scenario No. 13 is unavoidable. There is just one escape route from the scenario No.13, see the Figure2. The transition (a) can be done if the direct material costX_3 is (++ –) and the project durationX_1 is (+ – 0). The next step is the transition 10→9 which is again a conditional transition as it depends on the taxation.

5. Quantifications of trees probabilities

It is highly desirable to evaluate probabilities of all / some branches of the tree R (11) under study. However, the information shortage usually does not allow applications of traditional methods, e.g. statistics, see e.g.(Arora, Little and Mcsharry, 2013; Doubravsky and Dohnal, 2015).

Several different heuristics can be used to formalize common sense reasoning, e.g.

A longer tree branch is less probable (16)

A transition between two scenarios is less probable if more variables must be changed (17)

Examples of interpretations of (17) are:

If all n variables (3) *must be changed to move from* i-*th scenario to* j-*th scenario, then this transition is the least probable.*

If just one variable is changed to move between two scenarios, then this transition is the most probable.

The following algorithm is used to evaluate numerical probabilities of the tree (11) using the above mentioned heuristics:

ST Set of terminals, see (13), the Figure3.

N Set of all tree nodes (scenarios).

$l_{i,j}$ Number of changed variables in the transition of *i*-th scenario into *j*-th scenario.

$l_{12,11} = 1$, see (15).

L_i Number of changed variables of the sub-tree where *i* is the sub-root, i.e. variable resistance of *i*-th node.

$L_i = \sum_j l_{i,j}$, see e.g. $L_{12} = l_{12,10} + l_{12,11} + l_{12,13} = 7 + 2 + 2 = 11$, see the Figure3, (18)

where *j* represents nearest node (scenario) of the sub-tree next to the *i*-th node (scenario).

$l_{i,j}^* = L_i - l_{i,j}$, for all $i, j \in \mathrm{N} - \mathrm{ST}$, $l_{12,11}^* = L_{12} - l_{12,11} = 11 - 2 = 9$ (19)

L_i^* Sum of all changed variables for all transition of the *i-th* sub-tree: (20)

$L_i^* = \sum_j l_{i,j}^*$, see e.g. $L^*_{12} = l^*_{12,10} + 1^*_{12,11} + l^*_{12,13} = 22$ (21)

where*j* represents nearest node of the sub-tree next to the *i-th* node.

Let us suppose that the tree, see the Figure3, is a system of pipes and one litre of water per second is pumped into the root node No. 12. Simple common sense reasoning indicates that short branches have lower hydraulic resistance and therefore the water outflow from the nodes 11 and 12 must be higher than the outflow from the node No. 7, see the Figure3. However, the hydraulic resistance of each pipe, which represents a transition between two scenarios, must take into consideration the number of changed variables as well, see (17).

The following splitting ratios α are used to evaluate the flow of water through a tree, through each its branch:

$\alpha_{i,j}$ Splitting ratio from *i-th* node (scenario) to *j-th* node (scenario):

$\alpha_{i,j} = l^*_{i,j} / L^*_i$, for all $j \in \mathrm{N} - \mathrm{ST}$, see e.g. $\alpha_{12,11} = l_{12,11}^* / L^*_{12} = 9/22$ (22)

The heuristic (17) can be used to evaluate splitting ratios (22), see the Figure3.

$\alpha_{12,11} = 9/22 = 0.409$
$\alpha_{12,13} = 9/22 = 0.409$
$\alpha_{12,10} = 4/22 = 0.182$
$\alpha_{12,10} + \alpha_{12,11} + \alpha_{12,13} = 1$ (23)
$\alpha_{10,9} = 1/1 = 1$
$\alpha_{9,7} = 3/3 = 1$

The flow rate of water through each node is equal to its probability as the flow satisfies to all probability axioms, namely

for all $A \in \Omega,\ p(A) \geq 0$ (24)

$p(\Omega) = 1$ (25)

$p(A_1 \cup A_2 \cup \ldots \cup A_i) = \sum_i p(A_i)$ (26)

The probability p_r of a root node is always equal one as one litre per second of water.

$p_r = 1$ (27)

Non-root probability $p_{i,j}$ of the transition from *i*-th scenario into *j*-th scenario can be evaluated very easily by

$p_{i,j} = \sum_{i=1}^{k} \left(p_{k,i} \cdot \alpha_{i,j} \right),\ j \in (\mathrm{N} - \mathrm{ST})$ (28)

where *k* is the sub-root. The principle of calculation is shown in the following example, see the Figure3:

$p_{12,11} = 1 \times \alpha_{12,11} = 1 \times 0.409 = 0.409$; see (27), (28)
$p_{12,13} = 1 \times \alpha_{12,13} = 1 \times 0.409 = 0.409$
$p_{12,10} = 1 \times \alpha_{12,10} = 1 \times 0.182 = 0.182$ (29)
$p_{10,9} = p_{12,10} \times \alpha_{10,9} = 0.182 \times 1 = 0.182$
$p_{9,7} = p_{10,9} \times \alpha_{9,7} = 0.182 \times 1 = 0.182$

6. Case Study

A qualitative model, given in(Tran, Cheng and Cao, 2015; Sakellaropoulos and Chassiakos, 2004) has the following variables:

PPC	Direct personal costs	IOC	Indirect operating costs	
PMC	Direct material costs	TFC	Taxes and fees costs	(30)
PSC	Direct subcontract costs	PD	Project duration	
IPC	Indirect personal costs			

The following equation-less qualitative model (7)is based on the variables (30):

	X	*Y*	Shape, see the Figure1	
1	PD	PPC	24	
2	PD	PMC	23	
3	PD	IPC	22	
4	PD	IOC	22	
5	PD	TFC	22	(31)
6	PMC	PSC	26	
7	PPC	IPC	24	
8	PPC	IOC	24	
9	PPC	TFC	24	

The following set of 63 time scenarios exist if the equation less model (31) is used to generate them and all variables (30) are positive, it means that all triplets have the following general form (+, evaluate, evaluate). For example, any project duration is always positive by its very nature

	PPC	PMC	PSC	IPC	IOC	TFC	PD	
1	+ + +	+ – +	+ + –	+ – +	+ – +	+ – +	+ – +	
2	+ + +	+ – –	+ + +	+ – +	+ – +	+ – +	+ – +	
3	+ + +	+ – –	+ + +	+ – –	+ – –	+ – –	+ – –	
4	+ + +	+ – –	+ + +	+ – 0	+ – 0	+ – 0	+ – 0	
5	+ + +	+ – –	+ + –	+ – +	+ – +	+ – +	+ – +	
6	+ + +	+ – –	+ + –	+ – –	+ – –	+ – –	+ – –	
7	+ + +	+ – –	+ + –	+ – 0	+ – 0	+ – 0	+ – 0	
8	+ + +	+ – –	+ + 0	+ – +	+ – +	+ – +	+ – +	
9	+ + +	+ – –	+ + 0	+ – –	+ – –	+ – –	+ – –	
10	+ + +	+ – –	+ + 0	+ – 0	+ – 0	+ – 0	+ – 0	(32)
11	+ + +	+ – 0	+ + –	+ – +	+ – +	+ – +	+ – +	
12	+ + –	+ – +	+ + –	+ – +	+ – +	+ – +	+ – +	
13	+ + –	+ – –	+ + +	+ – +	+ – +	+ – +	+ – +	
14	+ + –	+ – –	+ + –	+ – +	+ – +	+ – +	+ – +	
15	+ + –	+ – –	+ + 0	+ – +	+ – +	+ – +	+ – +	
16	+ + –	+ – 0	+ + –	+ – +	+ – +	+ – +	+ – +	
17	+ + 0	+ – +	+ + –	+ – +	+ – +	+ – +	+ – +	
18	+ + 0	+ – –	+ + +	+ – +	+ – +	+ – +	+ – +	
19	+ + 0	+ – –	+ + –	+ – +	+ – +	+ – +	+ – +	

20	+ + 0	+ – –	+ + 0	+ – +	+ – +	+ – +	+ – +
21	+ + 0	+ – 0	+ + –	+ – +	+ – +	+ – +	+ – +
22	+ – +	+ + +	+ – –	+ + +	+ + +	+ + +	+ + +
23	+ – +	+ + –	+ – +	+ + +	+ + +	+ + +	+ + +
24	+ – +	+ + –	+ – +	+ + –	+ + –	+ + –	+ + –
25	+ – +	+ + –	+ – +	+ + 0	+ + 0	+ + 0	+ + 0
26	+ – +	+ + –	+ – –	+ + +	+ + +	+ + +	+ + +
27	+ – +	+ + –	+ – –	+ + –	+ + –	+ + –	+ + –
28	+ – +	+ + –	+ – –	+ + 0	+ + 0	+ + 0	+ + 0
29	+ – +	+ + –	+ – 0	+ + +	+ + +	+ + +	+ + +
30	+ – +	+ + –	+ – 0	+ + –	+ + –	+ + –	+ + –
31	+ – +	+ + –	+ – 0	+ + 0	+ + 0	+ + 0	+ + 0
32	+ – +	+ + 0	+ – –	+ + +	+ + +	+ + +	+ + +
33	+ – –	+ + +	+ – –	+ + +	+ + +	+ + +	+ + +
34	+ – –	+ + –	+ – +	+ + +	+ + +	+ + +	+ + +
35	+ – –	+ + –	+ – –	+ + +	+ + +	+ + +	+ + +
36	+ – –	+ + –	+ – 0	+ + +	+ + +	+ + +	+ + +
37	+ – –	+ + 0	+ – –	+ + +	+ + +	+ + +	+ + +
38	+ – 0	+ + +	+ – –	+ + +	+ + +	+ + +	+ + +
39	+ – 0	+ + –	+ – +	+ + +	+ + +	+ + +	+ + +
40	+ – 0	+ + –	+ – –	+ + +	+ + +	+ + +	+ + +
41	+ – 0	+ + –	+ – 0	+ + +	+ + +	+ + +	+ + +
42	+ – 0	+ + 0	+ – –	+ + +	+ + +	+ + +	+ + +
43	+ 0 +	+ 0 +	+ 0 –	+ 0 +	+ 0 +	+ 0 +	+ 0 +
44	+ 0 +	+ 0 –	+ 0 +	+ 0 +	+ 0 +	+ 0 +	+ 0 +
45	+ 0 +	+ 0 –	+ 0 +	+ 0 –	+ 0 –	+ 0 –	+ 0 –
46	+ 0 +	+ 0 –	+ 0 +	+ 0 0	+ 0 0	+ 0 0	+ 0 0
47	+ 0 +	+ 0 –	+ 0 –	+ 0 +	+ 0 +	+ 0 +	+ 0 +
48	+ 0 +	+ 0 –	+ 0 –	+ 0 –	+ 0 –	+ 0 –	+ 0 –
49	+ 0 +	+ 0 –	+ 0 –	+ 0 0	+ 0 0	+ 0 0	+ 0 0
50	+ 0 +	+ 0 –	+ 0 0	+ 0 +	+ 0 +	+ 0 +	+ 0 +
51	+ 0 +	+ 0 –	+ 0 0	+ 0 –	+ 0 –	+ 0 –	+ 0 –
52	+ 0 +	+ 0 –	+ 0 0	+ 0 0	+ 0 0	+ 0 0	+ 0 0
53	+ 0 +	+ 0 0	+ 0 –	+ 0 +	+ 0 +	+ 0 +	+ 0 +
54	+ 0 –	+ 0 +	+ 0 –	+ 0 +	+ 0 +	+ 0 +	+ 0 +
55	+ 0 –	+ 0 –	+ 0 +	+ 0 +	+ 0 +	+ 0 +	+ 0 +
56	+ 0 –	+ 0 –	+ 0 –	+ 0 +	+ 0 +	+ 0 +	+ 0 +
57	+ 0 –	+ 0 –	+ 0 0	+ 0 +	+ 0 +	+ 0 +	+ 0 +
58	+ 0 –	+ 0 0	+ 0 –	+ 0 +	+ 0 +	+ 0 +	+ 0 +
59	+ 0 0	+ 0 +	+ 0 –	+ 0 +	+ 0 +	+ 0 +	+ 0 +
60	+ 0 0	+ 0 –	+ 0 +	+ 0 +	+ 0 +	+ 0 +	+ 0 +
61	+ 0 0	+ 0 –	+ 0 –	+ 0 +	+ 0 +	+ 0 +	+ 0 +
62	+ 0 0	+ 0 –	+ 0 0	+ 0 +	+ 0 +	+ 0 +	+ 0 +
63	+ 0 0	+ 0 0	+ 0 –	+ 0 +	+ 0 +	+ 0 +	+ 0 +

It is relatively easy to generate the list of all possible transitions among 63 scenarios (32) using the Table1. There are 312 transitions, see the Figure4.

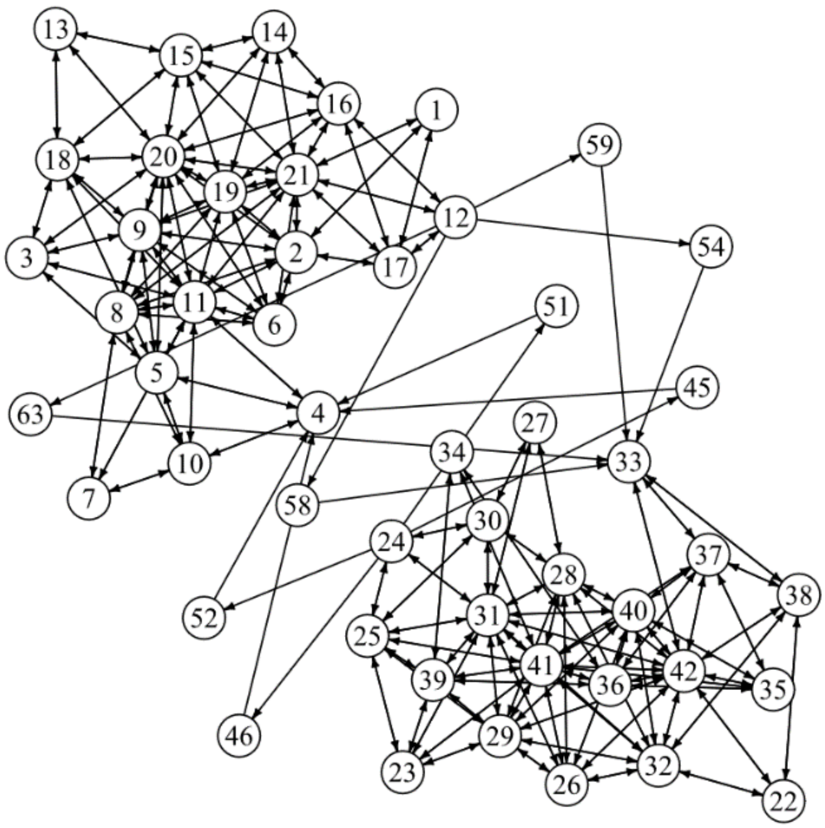

Figure4. Transitional graph based on the set of scenarios(32)

The Figure4 gives all possible oriented paths. It means that any future / past qualitative behaviour of the model (31) is represented by a sub-graph of the transitional graph in the Figure4.The scenarios Nos. 43, 44, 47, 48, 49, 50, 53, 55, 56, 57, 60, 61 and 62arenot included in the Figure4. They are isolated scenarios, which means that it is not possible to reach or leave these scenarios.

Any forecast is a result of decisions done by a decision. If a quantification of probabilities is required, then a qualitative tree must be chosen. A team of experts chooses suggests the following qualitative tree (11) to analysis, see the Figure5:

$R(S_1, \mathrm{ST}_1)$ where

$$\mathrm{ST}_{12} \equiv \{\mathrm{S}_{13}, \mathrm{S}_{15}, \mathrm{S}_{16}, \mathrm{S}_{58}\} \quad (33)$$

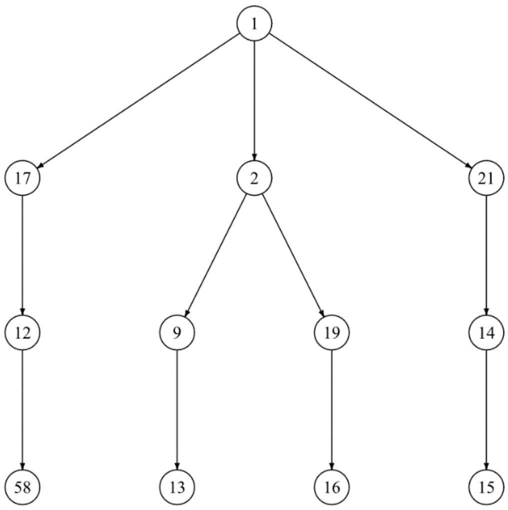

Figure5. Qualitative decision tree

The experts feel that the current situation is characterized by the scenario No. 12. Therefore, the root scenario is the scenario No. 12, see the Figure5. The terminal scenarios Nos. 13, 15, 16 and 58 express the decision makers' forecast.

The following paths are studied:

$$1 \rightarrow 17 \rightarrow 12 \rightarrow 58 \tag{34}$$

or

$$1 \rightarrow 2 \rightarrow 9 \rightarrow 13 \text{ or } 1 \rightarrow 2 \rightarrow 19 \rightarrow 16 \tag{35}$$

or

$$1 \rightarrow 21 \rightarrow 14 \rightarrow 15 \tag{36}$$

The qualitative decision tree theFigure5 allows determining the probabilities of each scenario (32) generated by equation-less qualitative model(31). The move from ***i***-th scenario to ***j***-th scenario, see the Figure5, is given by changes of variables (30). The following parts contain probability determining of each scenario by (18)–(28), see the Figure5, for all variables.

The transition from the scenario No. 1 to scenario No. 17, see (32), the Figure4 and the Figure5, requires the changes of 2 variables (30), see the Table2. The numbers of changed variables is needed to use the sub heuristics (17).

Table2. Changes of 2 variables

Node\Variable	BR	CB	D	EA	G	IP	R1	SSP	T	U
1	+ + +	+ – +	+ + –	+ – +	+ – +	+ – +	+ – +	+ + +	+ – +	+ + –
17	+ + 0	+ – +	+ + –	+ – +	+ – +	+ – +	+ – +	+ + 0	+ – +	+ + –

Numbers of changed variables for all transitions T_{ij} from the Figure5 are shown in the Table3.

Table3. Changes of variables

Scenario		Number of changed variables
From *i*	To *j*	
1	2	2
1	17	2
1	21	2
2	9	5
2	19	2
9	13	6
19	16	2
17	12	1
12	58	7
21	14	2
14	15	1

On base of number of changed variables, see the Table3, the probabilities (28) were obtained by splitting ratios (22), see the Table4.

Table4. Scenario probabilities

Scenario No.	Scenario Probabilities	Scenario No.	Scenario Probabilities
1	1	17	0.344
2	0.234	19	0.172
9	0.062	21	0.422
12	0.344	58	0.344
13	0.062		
14	0.422		
15	0.422		
16	0.172		

Interpretations of the results given in the Table4 is simple, the most probable terminal is the scenario No. 15. The probabilities of the terminals ST and consequently probabilities of the three's branches, see the Figure5.

The forecast based on the equation-less model (31) and the chosen tree, see the Figure5, is the list of branches and their probabilities.

7. Conclusion

The main advantage of a qualitative analysis is that no numerical values of constants and parameters are needed and the set of qualitative scenarios / solutions is provably complete. It means that a decision maker and / or forecaster has a simpler task to solve, namely to choose from given set of variants. No reasonable variant can be overlooked if the analysis is based on a feasible qualitative model.

Any genesis of a feasible qualitative model is an ad hoc procedure based usually on a dialog within a team of experts. It is often difficult to reach a mutually acceptable compromise. A choice of a qualitative decision tree as a subgraph of a transitional graph must reflect specific point of view. Each point of view is reflected by the corresponding qualitative tree. It means that several qualitative trees must be studied if complex tasks are analysed. Levels of subjectivity of the reached decisions are difficult to quantify.

There are many unsolved problems of qualitative modelling. For example, it is known that exist ineradicably spurious behaviours. Qualitative simulator must include them in its scenario sets, see e.g. (Dhawan, O'Connor and Borman, 2011). Some interpretation tasks are not fully understood, see e.g. (Arora, Little and Mcsharry, 2013). However, the above mentioned approximation algorithm is fully applicable. Any further development steps in qualitative modelling makes the forecasts better.

The time-cost analysis are complex tasks. The project managers use their experience and common sense; therefore, the common mathematical and statistical methods do not have to give any accurate or meaningful solution. The project managers' decision is done in advance and they try to predict the behaviour of the project. Hence, the qualitative tree is used. The main advantage of the qualitative tree method is that no numerical values are needed. The qualitative model gives all possible solutions; the transition graph shows the behaviour of the project, e.g. project costs, and the qualitative tree gives the probabilities of each scenario generated by qualitative model.

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