DECISION TREES – A PERSPECTIVE OF ELECTRONIC DECISIONAL SUPPORT

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ABSTRACT: Without substitute decision-maker, decision support system, through their components, can facilitate the work of decision-maker by providing useful clues to solving problems and identifying opportunities. Choosing an optimal solution in case of complex decision making processes, with a degree of uncertainty, involving a series of interdependent decisions, performed in several periods of time, can be achieved using decision trees. Suggestive and simple properties propel decision trees among the tools with a high degree of adoption and integration in electronic decisional systems.

Key words: tree, decision, risk, rollback, certainty

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Introduction

Decision support system is one of the best tools to assist decision making at the organizational level, in today's society, characterized by high complexity of business, global competition, information explosion, uncertainty, pronounced inconstancy and so on (Mărginean 2006). For all these aspects of contemporary, instruments must be identified for an appropriate handling and control. Without substitute decision-maker, decision support system, through their components useful in supporting all phases of decisional process, can facilitate the work of decision-maker by providing useful clues to solving problems and identifying opportunities.

Literature review

Choosing an optimal solution in case of complex decision making processes, with a degree of uncertainty, involving a series of interdependent decisions, performed in several periods of time, can be achieved using decision trees. According to Wikipedia, a tree is a decision making tool that uses tree graphs in modeling decisions together with their consequences. In analyzing the decision, a decision making tree is a visual tool used to support decision making through computing expected values of all decision alternatives in order to identify the best solution.

A decision tree consists of multiple nodes connected by edges. Nodes of a decision tree can be of three kinds:

- decision nodes represented by squares;
- event nodes represented by circles;
- terminal nodes represented by triangle or vertical line..

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Decision node represents the point where decision-maker is able to choose one of several possible variants. Edges that start from this node represent decision alternatives or options. The decision nodes and edges represent the controllable factors of decision making.

An event or chance node represents a point of uncertainty in decision making where can occur more events. Edges that start from such a node represent possible events that can occur at that point. Through event nodes are represented uncontrollable factors of decision making.

Each edge of the decision tree has attached a label with her meaning and a value representing the cost or benefit that is obtained by choosing the action attached to the edge in question. In addition, event type edges have attached the probability of occurrence for events they represent.

Terminal nodes are the final paragraphs of the decision tree and represent the outcome of a sequence of decisions and events. Each terminal value is obtained by summing all the values attached to the edges found on the unique path from the initial node of the decision tree to the current terminal node. Thus it can say that the final value of a node quantifies a scenario to consider for identifying the optimal solution.

In the context of decision tree "roll back" algorithm determines the optimal sequence of decisions and events. Firstly, it is calculated the optimal decision at the last decision point, after optimal mathematical expectation criterion. Then it is proceeded the decision selection for the following decision point upstream, thus going step by step up to the initial decision point (Stănciou.1998). In other words, the algorithm "roll back" are applied on the decision tree going through the terminal toward the initial node, where for each node are computed the so-called rollback value of certainty. This value is positioned in the lower left of each node and is calculated based on the decision-maker attitude towards risk.

The essence of decision making is a complex process that often involves a less or greater uncertainty. One way to quantify the uncertainty is based on the probability theory. Each uncontrollable event can occur in a certain given situation and has attached some probability of occurrence, computed on the basis of existing statistical data, collected over time. Thus, to characterize the uncertainty of a one situation, it is used the probability distributions that synthesize all possible events associated with their likelihood. A synthetic view of a probability distribution for a certain situation is given by the expected value. Expected value is a criterion for choosing a decision in conditions which it is taken account all possible outcomes and their likelihood. Expected value of economic actions is given by the sum of the values obtained by multiplication of the values (benefits or costs) associated to the events and their likelihood of occurrence.

$$E(X) = \sum_j x_j P(X = x_j) \quad \text{..................................} \quad (1)$$

In case the expected value is accepted by a decison-maker as a result of actions, it can speak about a position of neutrality towards risk. Decision-maker accept in the same time the possibility of winning and the possibility of loosing. For example, in situations where in a certain decision point it can be identified two variants, a gain (100RON) and a loss (-50RON) with the same probability, expected value is 100 * 0.5 -50 * 0.5 = 25RON. In the case of neutral attitude towards risk, decision-maker has the same attitude both for the situation of certain alternative of 25RON equal to expected value and for situation of uncertain alternative described by a gain (100RON) with 50% probability and a loss (50RON) with the same probability.

In the case of neutral attitude towards risk and a maximization problem, for all nodes will be computed rollback values as follows:

- for terminal node, Rollback values are equal to terminal value;
- for event node, Rollback values are equal to expected value of that point ;

• for decision nodes, Rollback values are equal to maximum of the rollback values situated to the immediately succesor nodes.

Bussiness practice proved that in decisional field is presented the phenomenon of risk aversion. It is prefered certain low benefits against uncertain high benefits. For previous scenario, decision-maker prefers to win an amount smaller than expected value (25RON) against to adventure him in the presented uncertain situation. In this case it is necessary to identify a new indicator that replace the expected value. If expected value caracterizes sintetically the outcome of the uncertain situation with neutral attitude towards risk, certainty equivalent will caracterize the outcome of the uncertain situation with risk aversion. Firstly, the new indicator supposes adjusting the likelihood of the events with exponential utility function having the next form:

$$U(x) = A - B * EXP(-x/RT) \qquad (2)$$

where:

- x – obtained outcomes
- RT – tolerance to risk – is a parameter that quantifies the attitude towards risk of decision-maker, having a value equal with the maximum amount Y where decision-maker accepts the scenario

$$\begin{pmatrix} Y & -Y/2 \\ 0.5 & 0.5 \end{pmatrix} . \qquad (3)$$

against to a certain null gain.

- The most unfavorable outcome(valmin) has the utility equal to 0.
- The most favorable outcome(valmax) has the utility equal to 1.
- A=EXP(-valmin/RT)/[EXP(-valmin/RT)-EXP(valmax/RT)]
- B=1/[EXP(-valmin/RT)-EXP(valmax/RT)].

Expected utility for an uncertain situation having probabilistic distribution (x,P(x)) is computed according to the next formula:

$$EU = \sum P(X = \chi_i) * U(\chi_i) \qquad (4)$$

Once expected value is computed, the corresponding certainty equivalent will be computed using the next formula:

$$CE = -RT * LN[(A - EU)/B] \quad \ldots \qquad (5)$$

In the case of risk aversion and maximization problem, for all nodes will be computed both rollback values and expected utilities. Thus:

• for terminal node, rollback value is equal with terminal value; having terminal value, can be computed the corresponding utility;

• for event node, it is computed expected utility and then rollback value is equal to certainty equivalent;

• for decisional node, rollback value is equals to maximum of the rollback values situated in the immediately succesor nodes; having rollback value can be computed expected utility.

Considering that the only decision nodes are controllable factors, possible strategies for action, starting from a certain decision tree, are given by the sequence of all relevant options from decision nodes.

After Rollback method was applied, identifying Rollback values of all nodes, the optimal strategy can be identified easily. Key decision-related variants that determine the optimal strategy is the Rollback values located around to decision nodes. Within one decision node, the output decisional variant that has the rollback value identical with the Rollback value of the input decisional variant represents one component of the optimal strategy. On this occasion, within decision node, represented by a square, it will be placed the order number of decisional variant that satisfies the above condition so that optimal strategy will be identified easily by scrolling sequential decision nodes and taking the decisional variants whose sequence number is presented within decision nodes.

Research methodology

Solving a practical decisional problem by the usage of decision trees can emphasize their main characteristics in a clearer manner and their utility for decision-maker. Let's consider the following situation (adapted from Middleton 2003):

A firm wants to develop a new product. Since the firm hasn’t experience in developing such products, it will be appealed to an external firm through the organization of an auction. Current firm X wants to sign up for the auction. In case the auction would have won, company X would have an income of 200000EUR. To register to bid and to elaborate all the necessary documentation, company X will spend 50000EUR. Management of Company X believes that chances of winning the auction are 50%. Company X has three ways to provide that product manufacturing:

- a manual way to guarantee getting a product as required by the beneficiaries and whose cost is 100000EUR
- a semi-automatic way to guarantee getting a product according to customer's requirements only in proportion of 50% and whose cost is 40000EUR
- a automatic way to guarantee getting a product according to customer's requirements only in proportion of 70% and whose cost is 70000EUR

In case semiautomatic or automatic manufacturing way fails, it will be chosen the manual method. It is required to identify the optimal strategy both for neutral attitude towards risk and for risk aversion.

Generation of decision trees and application of their algorithms is among the concerns of many software producers. Software packages as Lumenaut Decision Tree, TreeAge Software, Vanguard Software, TreePlan, GraphViz and so on, provide a range of tools that enable us to build easily and quickly decision tree models for many real life situations. Within these tools can find the Treeplan add-ins, a very useful extension of computer application Microsoft Excel, by which were automatically generated decision trees of the problem presented for both neutral version and variant of aversion risk.

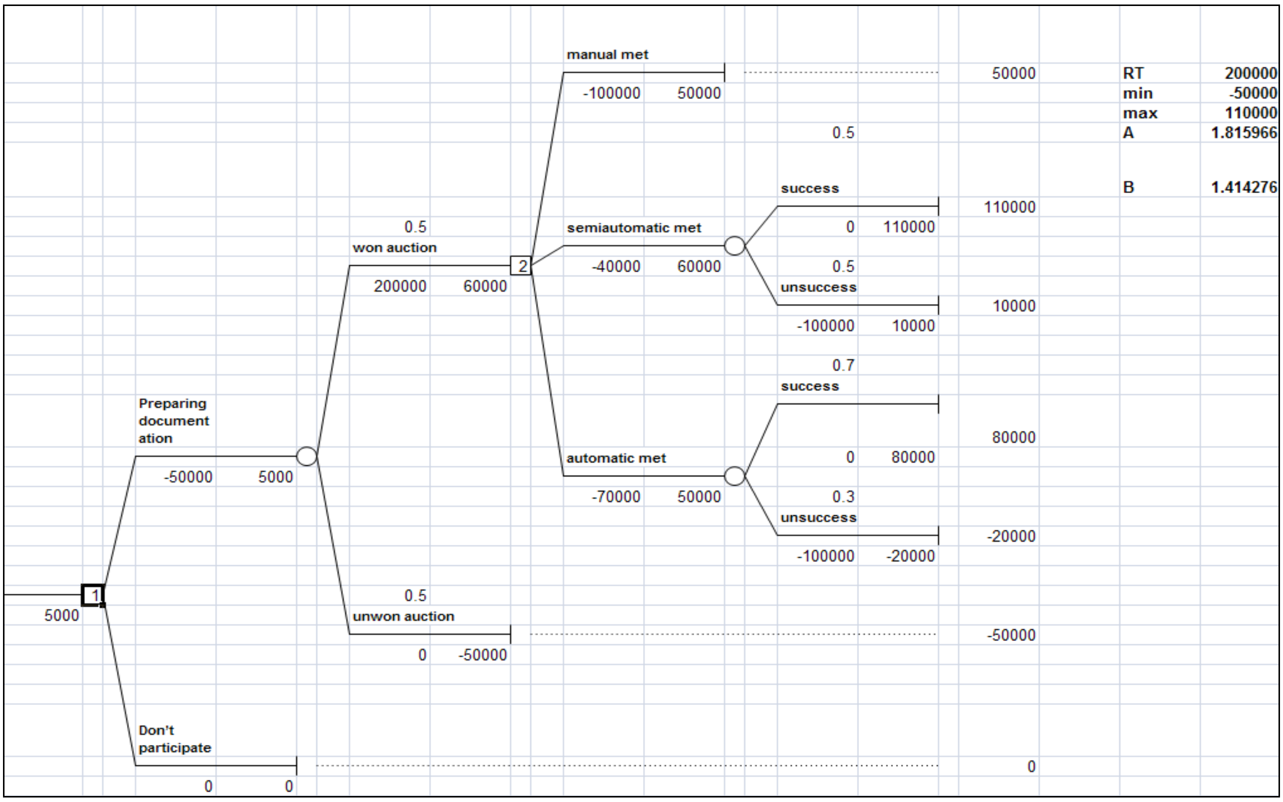

Fig. no.1 - Decision tree in the case of neutral attitude towards risk

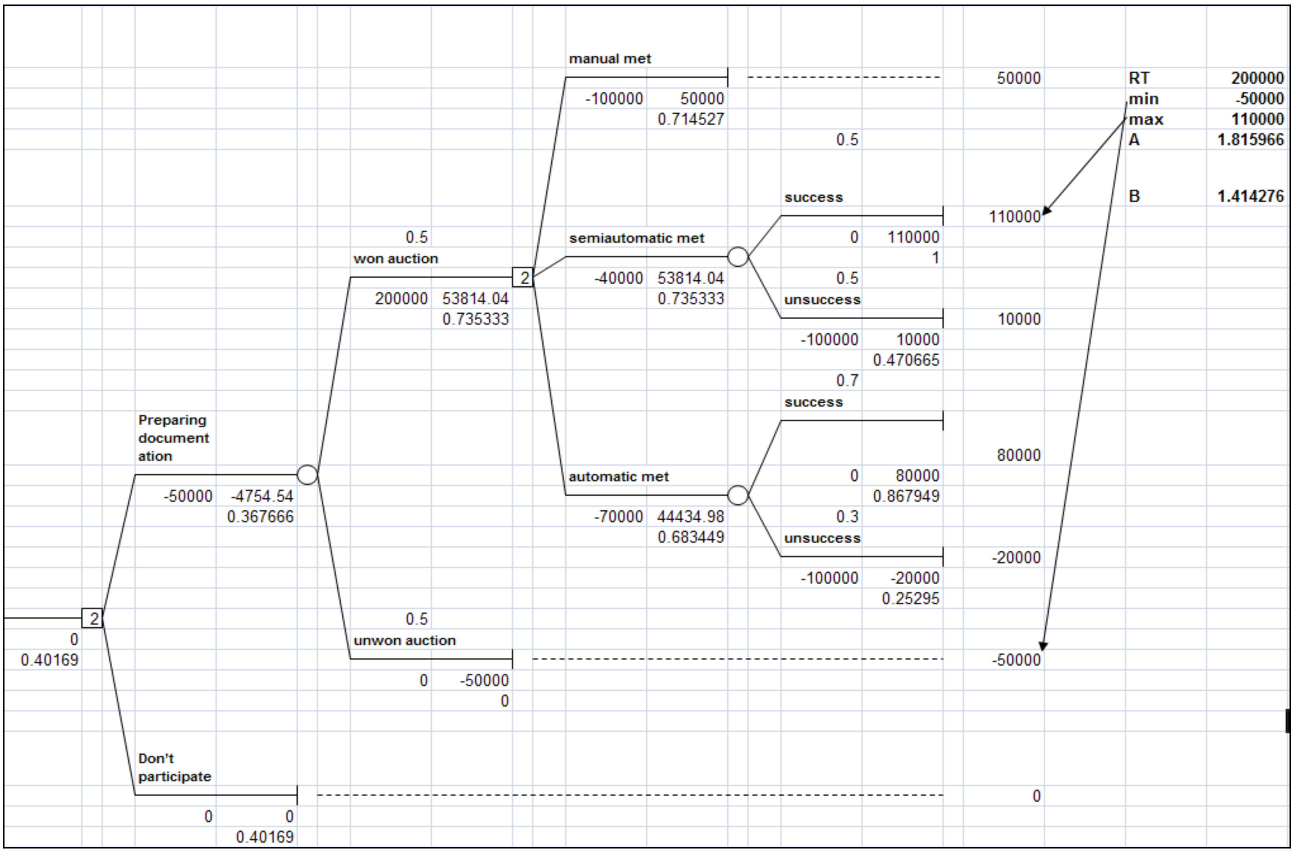

Fig. no.2 - Decision tree in the case of risk aversion

For the first case (fig. no.1), the above decision tree highlights the optimal decision strategy that consist of choosing the first option - preparing documentation (1) - and choosing the second option - semi-automatic method for manufacturing process (2)- from the next decision node.

In the second case (fig. no.2), decision-maker manifests a risk aversion attitude, accepting to bet for a maximum gain having amount 200,000 with a probability of 50% or loss 100 000 with the same probability. The decision tree indicates that with such a profile regarding risk, the best solution is to not participate in the auction (2).

Sensitivity analysis method applied to the obtained decision tree may reveal important aspects of its behaviour, regarding the model sensitivity to changes of different parameters of the problem. A good example in this regard is the identification of the decision-maker profile that joins the auction. Otherwise said, we study the model sensitivity to parameter changes in RT and we identify the point where the optimal variant is changing.

RT	ID	RT	CE
100000	2	100000	0
120000	2	120000	0
140000	2	140000	0
160000	2	160000	0
180000	2	180000	0
200000	2	200000	0
220000	2	220000	0
240000	2	240000	0
260000	2	260000	0
280000	2	280000	0
300000	2	300000	0
320000	2	320000	0
340000	2	340000	0
360000	2	360000	0
380000	2	380000	0
400000	2	400000	0
420000	1	420000	115.1889
440000	1	440000	328.0174
460000	1	460000	523.1272
480000	1	480000	702.6366
500000	1	500000	868.3402
520000	1	520000	1021.768
540000	1	540000	1164.232
560000	1	560000	1296.866

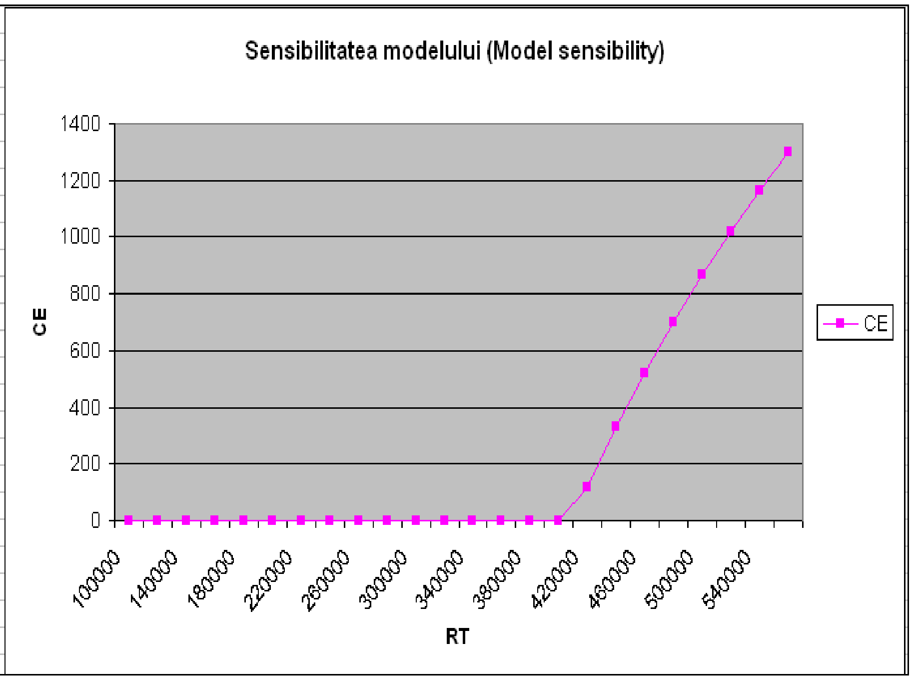

Fig. no. 3 - Model sensitivity at the changing of RT parameter

In the above figure (fig. no.3) ID = 1 has as meaning the participation to the auction while ID=2 means the giving up to sign up for the auction. As it can see, in the current problem, a greater value of RT than 420000 means that decision maker is willing to sign up for the auction. In other words, decision maker will sign-up for the auction when he is willing to bet on a scenario within can earn maximum 420000RON with probability of 50% or can lose 210000RON with the same probability.

Conclusions

A decision tree provides a consistent picture of a decision situation through the alternatives that are figured, through potential consequences of these, by presenting the main uncontrollable external factors with their probabilities of occurrence and by presenting the output results of action strategies. In conditions of uncertainty represented by probabilities, applying algorithm Rollback on the decision tree provides an optimal strategy to follow for a certain decision problems. The using of decision trees supposes mainly 4 steps:

- problem structuring in a decision tree form;
- attaching probabilities to event edges;
- assigning benefits/costs for the edges of decision tree;
- choosing the optimal strategy applying Rollback method both neutral attitude regarding risk and risk aversion.

There are many software packages that allow to decision-maker quickly to model real life decision processes and select the decision path that produces either the highest or lowest outcome, obtaining an optimum solution for their business. With an intuitive interface and graphical output these packages are practical for anyone - expert or not - to apply the analytical strengths of decision analysis to virtually any decision problem. As tool of electronic decisional support, decision trees meet the conviviality requirement of decision support system. Every decision maker can understand decision tree models after a previous short explanation. Suggestive graphical representation of a decisional situation using decision tree has all chances to be adopted and integrated among the working tools of many decision-makers.

Furthermore, finding a solution for decisional problems using decision trees supposes attending the main stages of decision making: analysis, modelling, the choosing a solution and its implementation. In other words, the software tools based on decision tree can provide support for all phases of decisional process.

Another advantage of decision trees is the possibility of combining them with other decision techniques. Net Present Value or making use of Monte Carlo type simulations are just two examples. For instance, in situations where certain values can not be expressed with a 100% certainty, Monte Carlo simulation offers a solution for that decisional problem in probabilistic terms.

As a final conclusion, for making decisions in a certainty or uncertainty economical context, the tools based on decision tree analysis technique can be applied with success to many different project management situations.

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