Computer-Based Decision Support for Railroad Transportation Systems: an Investment Case Study

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In the last decade the development of the economical and social life increased the complexity of transportation systems. In this context, the role of Decision Support Systems (DSS) became more and more important. The paper presents the characteristics, necessity, and usage of DSS in transportation and describes a practical application in the railroad field. To compute the optimal transportation capacity and flow on a certain railroad, specialized decision-support software which is available on the market was used.
Keywords: *decision support systems, decision tree, logistics, optimization, railroad transportation*

1 Introduction

In the modern society the mobility is an essential feature. The economical development requires the development of transportation systems (TS). The European Union has a clear policy in the domain of transportation systems and elaborated the main objectives of this important economical field. The White Paper of the European Commission [1] proposes 60 measures to aim at developing a European transport system "capable of shifting the balance between modes of transport, revitalizing the railways, promoting transport by sea and inland waterways and controlling the growth in air transport". In that document, the Intelligent Transportation Systems (ITS) have an important place since they have the potential to provide solutions for the 21st century European transportation. Those solutions take into account the transportation efficiency and velocity as well as its security of passengers. The other non-European states, as USA, Australia or Japan, elaborated transportation strategies for supporting the sustainable development of their societies.

Specific constituents of ITS are Decision Support Systems in Transportation (DSST), which are utilized at the operational and organizational management levels. These are intelligent systems that support the decider–a human being or a group of persons - in approaching complex situations and decision making processes. In the transportation field, the usage of such intelligent systems has certain advantages such as a) taking into account all the possible decisional scenarios, b) querying large data bases, c)quick elaboration of the optimal decision, and d)friendly interface communication [2]. In some cases, general-purpose decision analysis software products from-the shelf may suffice as it will be described later in this paper.

In this paper a review of the characteristic features of the DSS in transportation is made first. Then an application of a decision analysis tool to an investment problem in the Romanian railroad development is presented.

2 Characteristics of the DSS in Transportation

Decision Support Systems (DSS) ensure the computer-based support for the conscientious decision-making for solving problems that require large amount information processing and development of complex scenarios using this information [3]. A description of DSS usage, technology and construction is given in [4]. Decision Support Systems are interactive, computer-based systems that help the decision makers to solve complex, unstructured or semi-structured decision problems where a human expert assistant (or a group of assistants) would be otherwise needed.

The typical characteristics of a DSS are:

- specialization: each DSS is adapted to the informational necessities of the particular domain decision problem and decision maker and utilizes, beside general IT tools, specific tools for decision analysis;
- complexity: a DSS system is dealing with complex decision problems that "count". It, sometimes, needs a large amount of information about the approached decision situation; such a system also provides complex tools for risk and sensitivity analysis.

• friendly interfacing: almost all DSS have "usable" interface with the decision -maker that makes their usage more comfortable.

In addition to the above mentioned general features, some DSST integrate intelligent technologies that are able to facilitate the learning of previous special situations. There are some unexpected situations that may occur in a transportation system and the experience gained in solving such cases may be used in their future analysis.

Moreover, the architecture of a DSST must be modular, since the dynamics of the transportation systems imposes changes and adaptations to the clients and market needs. The newest communication and information technologies must be used to permanently modernize and evolve a DSST. Most of the DSST operation is based on the spatial DSS [5] and include GIS (Geographic Information Systems) and/or GPS (Geographic Positioning Systems) subsystems as specific constituents.

The main particular characteristics of DSST are:

• ensuring the safety of the passengers' transportation;

• reducing the costs of logistics or transportation procedures;

• optimizing the human/material traffic;

• allowing multi-criteria analysis;

• suggesting real-time solutions in case of incidents or urgent situations;

• providing with advanced remote control solutions.

As shown in the sequel, for some applications, general – purpose decision analysis tools may suffice.

3 Railroad transportation in Romania: a brief history

To set the stage for the decision analysis, a short excursion into the history of Romanian railways is made in the sequel following the lines exposed in [6]. The first railway line on present-day territory of Romania was opened on 20th August 1854 between Oravița (in Banat region) and Buziaş (a port on the Danube).

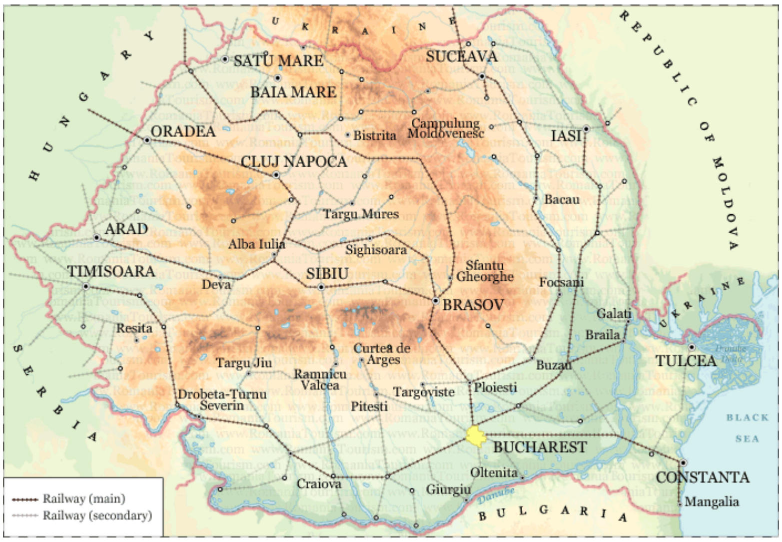

Fig. 1. Romanian railway network [11]

In 1918, in the Kingdom of Romania, the railway lines linked old and new Romanian regions (some of them previously in Austro-Hungarian Empire, others in Tsarist Russia), and were placed under the administration of Romanian Railway Company (CFR). After 1947, one could notice a very important amount of investment in railway infrastructure as compared with other forms of transport infrastructures. In Fig. 1 the network of main Romanian railways is presented.

After 1989, Romania inherited one of the largest, very dense, and frequently-utilized railway networks in Europe, which has, at the same time, a relatively outdated and partially worn-out infrastructure. This situation, combined with the economic decline that Romania faced in the 1990s due to its transition to a market economy, resulted in CFR entering in a period of noticeable relative decline. In the early 2000s, CFR started on a comprehensive modernization program with a view to improving its quality of services and image.

4 An investment decision problem

The context of our study is the necessity of the Romanian Railway Company (CFR) to supply an enhanced railroad capacity on the trans-Carpathian lines. This is a result of the development of two international railways: “Corridor IV” (from west to east) and “Corridor IX” (from north to south). Both corridors are breaking through the Southern Carpathian Mountains [7].

The decision–makers have to take into account some technical alternatives to increase the transportation flow capacity on these lines. One alternative is to multiply three or four times the capacity of the existing railroad lines between Bucharest and Ploiesti. Another solution is to finalize the work on the line Vîlcele – Bujoreni Vîlcea, but taking into consideration the construction risks on an unstable sliding natural ground. There is a third alternative, that of finding a new railroad between Pitesti and Rîmnicu Vîlcea. This railroad will pass from Bradu de Sus to Ioneşti-Vîlcea and will have certain advantages in respect of the land stability and construction investment costs.

The new possible railroad links are graphically drawn with solid thick lines in Fig. 2. . In the sequel the decision analysis will take into account the investments costs and the annual profit.

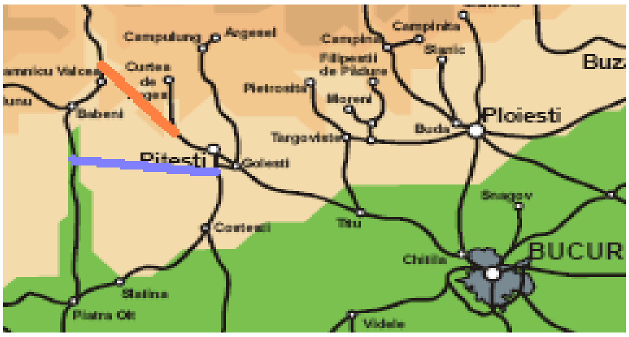

Fig. 2. New railway possible links between Piteşti and Rîmnicu Vîlcea

5 Palisade’s Precision Tree® - a practical decision tool

The Precision Tree® of Palisade is an example of decision analysis software which can be utilized as an add-in to Microsoft Excel® [8], [9].

The Precision Tree® system includes various tools for defining and analyzing decision trees and influence diagrams. In the software product, all decision model values, including the probabilities, are entered directly in spreadsheet cells, just like any other Excel models. It also allows linking values in the decision model directly to locations specified in a spreadsheet model. The results of solving that model can be utilized as payoffs for each path through the decision tree. All calculations of payoffs happen in real-time, that is, as the tree is edited, all payoffs and node values are automatically recalculated.

As shown in product description, the decision analyses supported by Palisade’s software can provide with several types of reports such as statistical reports, risk profiles and policy suggestions. All analysis results are reported directly in Excel for easy customization, printing, and saving. The user has not to learn a whole new set of formatting commands since all reports can be modified like any other Excel® worksheet or chart. More possible decision options can be added because the decision trees can be easily expanded, Palisade’s Precision Tree® also includes a set of features which are meant to help the user to reduce a tree to a more convenient size. All nodes can be collapsed, hiding from user’s view all paths which follow the node. A single sub-tree can be referenced from multiple nodes in other trees, saving the re-entry of the same tree over and over [8].

6 Experimental Results

As stated above, our decision analysis took into account four alternatives such as:

- (A1): increasing the transportation flow three times between Bucharest and Ploiesti,
- (A2): increasing the transportation flow four times between Bucharest and Ploiesti,
- (A3): constructing Vîlcele – Bujoreni Vîlcea railroad segment, and
- (A4): building the alternative railway segment Bradu de Sus to Ioneşti-Vîlcea.

The decision alternatives and their characteristics (considering both freights and passenger transport) over the next 25 years are synthetically given in the Table 1 [10]. The corresponding decision tree was constructed by using Precision Tree® 1.0 for Excell (Fig. 3). Note for each alternative three possible traffic values (high, medium, and low) with their associated probabilities were considered.

The policy suggestion is given in the figure 4 bellow as a result of running the procedure of rolling-back the decision tree. The optimal decision is found to be the third alternative of investment that is to finish the railway Vilcele – Bujoreni. The risk profile is given in the Fig. 5. The graphic representation shows that the probability to gain an annual profit over 2 billions euro is 65% if one decides to finish and to exploit the railway Vilcele – Bujoreni.

Note. All screen captures of figures 3 through 7 were obtained by using the Palisade Precision Tree® software.

Table 1. Characteristics of the decision alternatives [10]

	A1		A2		A3		A4	
	PT	FT	PT	FT	PT	FT	PT	FT
	3.00	4.00	3.00	4.00	3.00	4.00	3.00	4.00
Trains / day	6	12	10	20	16	32	16	32
Length of the segmentkm]	59	59	59	59	39	39	50	50
Total length/day	354	708	590	1,180	624	1,248	800	1,600
Anual revenues from TUI [€]	1,421,310.00		2,368,850.00		2,505,360.00		3,212,000.00	
Annual revenue from other sources [€uro]	45,000.00		50,000.00		550,000.00		650,000.00	
Total annual revenue [€uro]	1,466,310.00		2,418,850.00		3,055,360.00		3,862,000.00	
Annual running costs [€uro]	1,000,000.00		1,600,000.00		1,800,000.00		1,750,000.00	
Annual profit [€]	466,310.00		818,850.00		1,255,360.00		2,112,000.00	

Legend: PT: passenger trains; FT: freight trains; TUI: fee for using the infrastructure

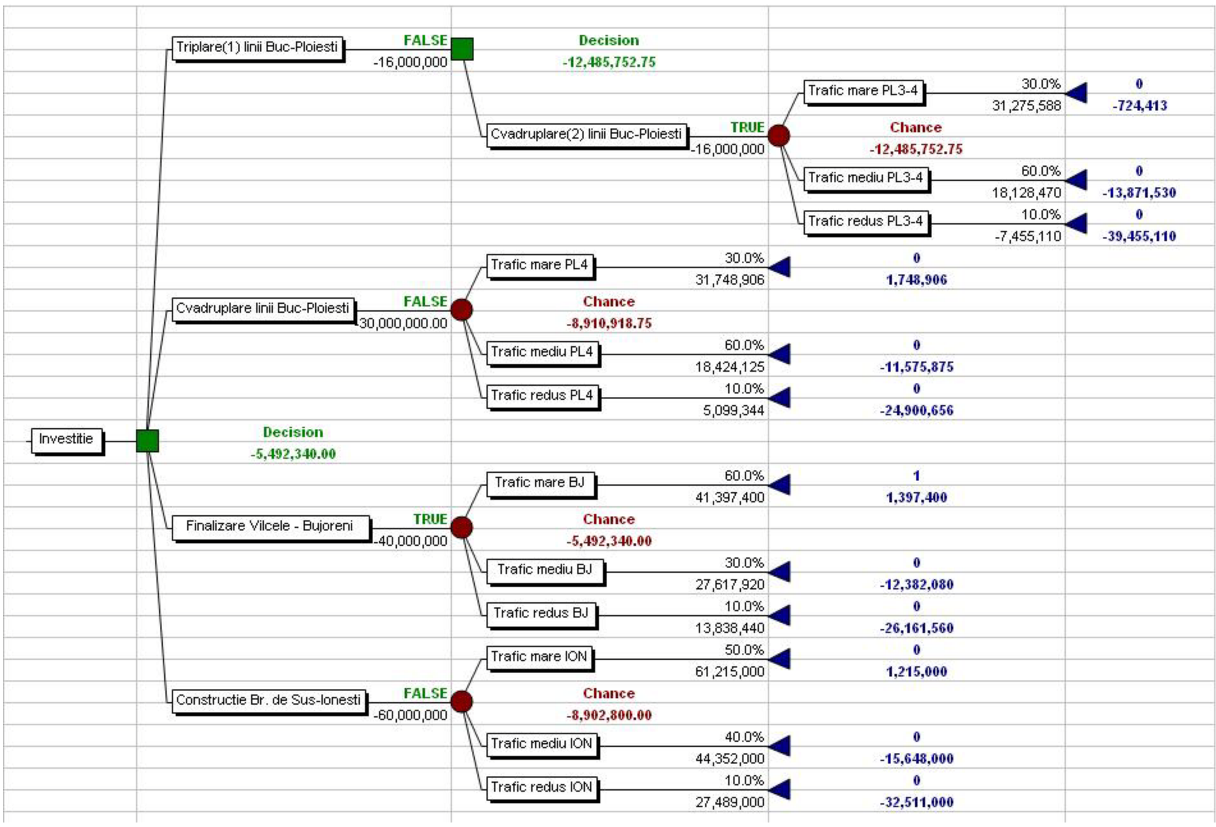

Fig. 3. Decision tree for alternatives of railroad capacity enhancing

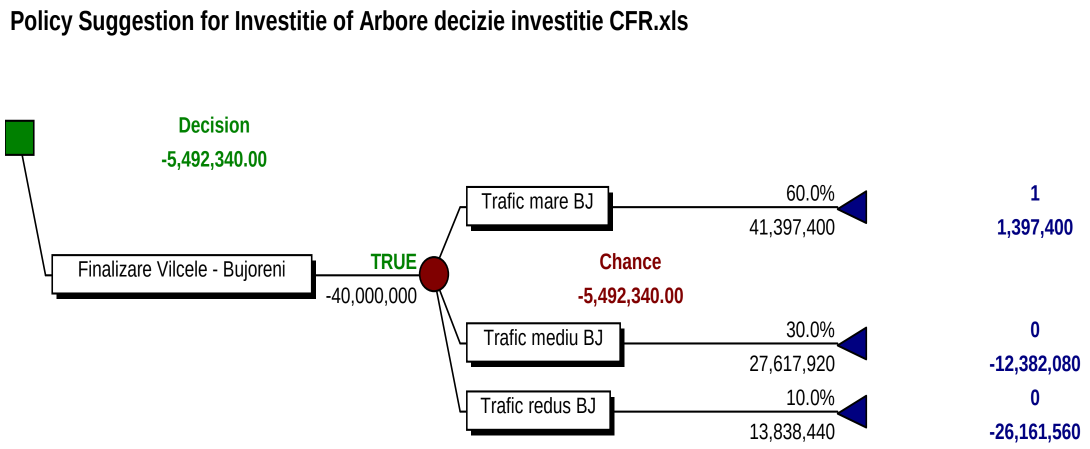

Fig. 4. Policy suggestion tree

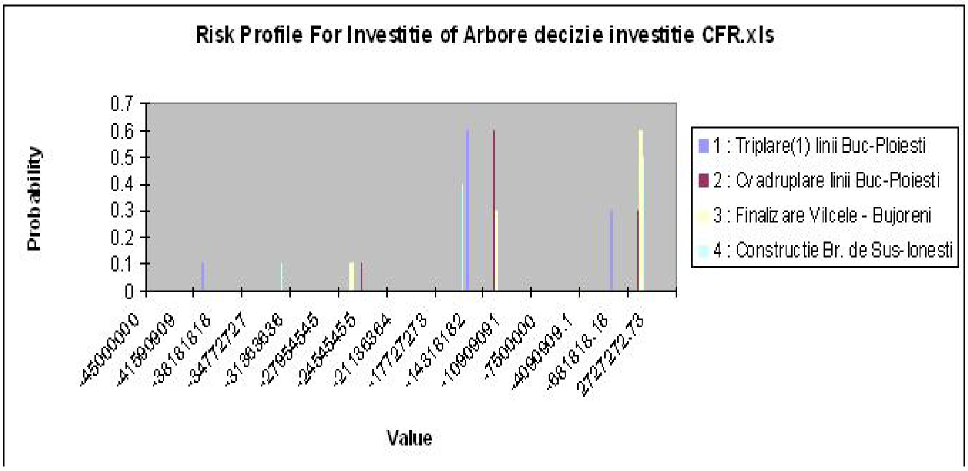

Fig. 5. Risk profile

The cumulative risk diagram (Fig 6) also shows that the probability to have loses in the case of the third decisional alternative is under 40%.

Spider graph (Fig. 7) compares the results of multiple analyses. For each variable, the percentage of the base case is plotted on the X-axis and the expected value of the model is plotted on the Y-axis. The slope of each line depicts the relative change in the outcome per unit change in the independent variable and the shape of the curve shows whether a linear or non-linear relationship exists. In Fig. 7, the total variation in the third decisional alternative (that to finish the railway Vîlcele – Bujoreni) has the largest total effect on expected value. Spider graphs show the reasonable limits of change for each independent variable and the unit impact of these changes on the outcome.

Some other simulation results show that only in the case of very low railway traffic between Pitesti and Rîmnicu Vîlcea, the third alternative is not the optimal one. In this latest case, multiplying four times the capacity line between Bucharest and Ploiesti could become the optimal investment alternative.

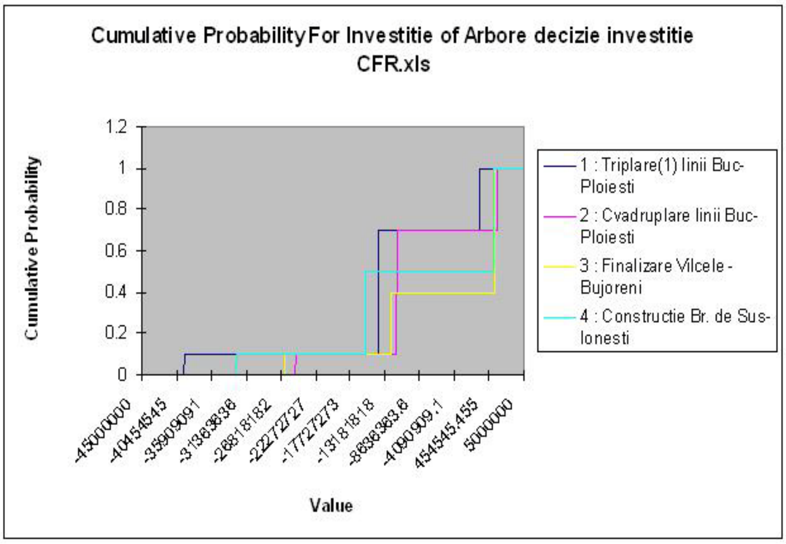

Fig. 6. Cumulative risk profile

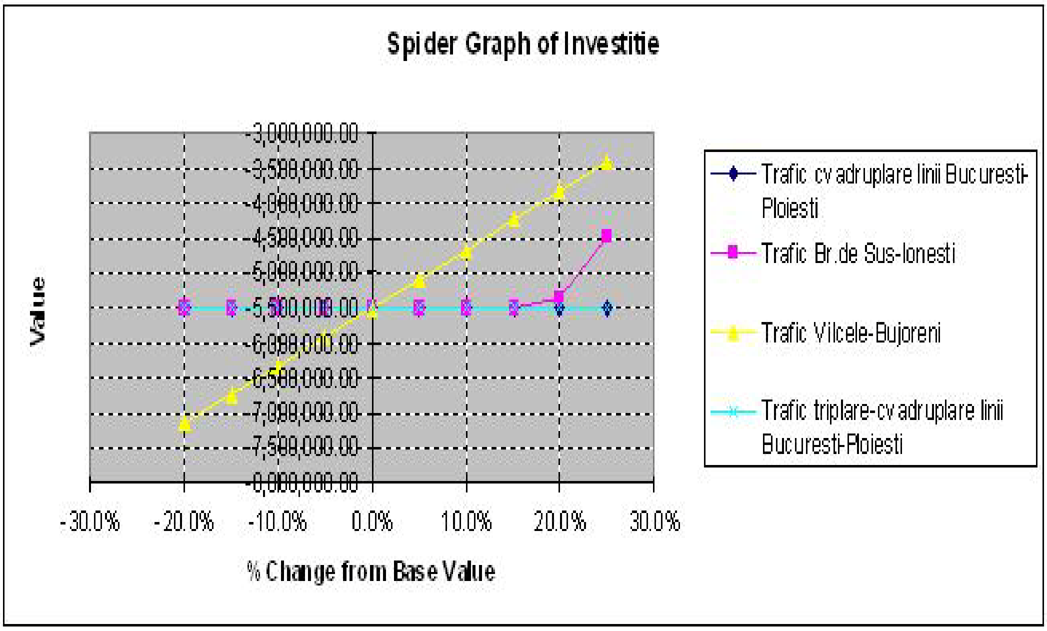

Fig.7. Spider graph

7 Conclusions

A thorough decision analysis concerning the investment for supplying the railroad capacity on the trans-Carpathian lines was made in this paper. To support the decision analysis, Precision Tree® a software product of Palisade was utilized. The presented study witnessed how usable and useful such a class of computer-supported decision analysis software tool (which includes several other products such as DPL7® of Syncopation (www.syncopation.com), TreeAge Pro® of TreeAge (www.treeage.com) , Analytica® of Lumina (www.lumina,com) to mention only a few examples) can be.

It is worth mentioning that a only single- attribute decision analysis was performed in our study. The evaluation criterion utilized in our analysis was the maximization of the annual profit of the Romanian railway company over the next 25 years. In future works, we will take into account a multi-criteria decision analysis, by introducing several new attributes to form a set of indicators which should be mutually independent and collectively complete.

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