Introduction to Decision Support Software

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1 Introduction

Decisions are an everyday experience in our life though most of them are quite trivial and made in an instant without much thinking. However, other decisions are too important and too complex for relying on personal experience or intuition and might require professional advice. Often enough even experts themselves want to consult some colleagues to verify their own judgment. Unfortunately, there is not always an appropriate expert at hand when needed and it is very expensive to keep one in waiting especially when the expertise is only needed infrequently.

A consulted expert usually reverts to rules in order to balance all data submitted before giving advice. Based on experience an expert knows which influencing factors are more or less important. The question is now if decision makers could not be more independent if these methods were standardized and written down to support simple decisions. On the other hand, experts could concentrate on rule building instead of having to cope with standard questions anymore. Thoughts like those led to the development of decision support systems.

Everyone is familiar with very simple decision support as for example signs that tell people what to do in case of a fire. Other decisions require much more data than 'fire' or 'no fire' but they may also be formulated as a set of rules and written down on a sheet of paper. With the ongoing distribution of computers, it is only logical to build the experts' knowledge, or at least the essential parts, into a computer program.

The core of any decision support system is a model of all rules enclosing smaller decisions and uncertain factors. Almost equally important is the user interface for data input and output. While some systems gather their data automatically from external sources like sensors, most of them require manual input from a user. At the other end of the processing chain, the results have to be visualized with graphs or other methods. However, the final decision has always to be made by the human decision maker who should have the option to comprehend the whole process.

Decision support systems are generally customized for a specific purpose and can rarely be reused. Lately there have been interesting developments in so-called decision analysis software. It allows for graphically structuring the rules into a clear model and offers numerous functions to vary all values. Linkages to spreadsheet cells are suitable for integrating whole data ranges dynamically into the model. In certain cases, these applications may replace a custom-tailored system.

On the following pages, certain decision analysis tools are evaluated concerning their suitability for decision support and monitoring purposes. For a better understanding of their application and their functionality, first a few examples of decision support will be described followed by a short introduction to decision theory.

2 Examples of Decision Support

Because decisions are very common there is a broad application range, but the emphasis clearly lies on the professional use. The following qualitative cases present a few circumstances in which decision support could be helpful.

2.1 Medical Decision Support

A doctor gets a young athlete with a serious infection on his foot that has become gangrenous. He has to decide if the foot has to be amputated soon implying a dent for the patient's livelihood or if is worth to try further antibiotic treatment with the risk of losing the whole limb or even the life. A decision support system can offer common experience and statistical data in such situations. Together with his patient, the doctor may weigh all possible outcomes of the model to find an acceptable treatment. However, that do not mean there is nothing to loose anymore, but the involved parties may get a better estimation of all risks and possibilities. (A tree for another medical treatment decision is shown on page 10.)

2.2 Geological Decision Support

Decision support is sometimes used by the oil industry when deciding whether to run a geological test on a prospective site. Though testing is much cheaper than drilling blindly into an empty site, it still cannot guarantee a success. It only helps to clarify the probabilities of the possible outcomes. A decision tree for this problem branches at first into the 'Test' or 'No test' alternatives. After the 'Test' branch, a chance node divides into the possible test results, which may occur with a certain probability. In the next level the decision whether to drill or not appears on all three result branches, just as on the 'No test' branch of the ingoing test decision too. (A part of the corresponding decision tree may be seen on page 15.)

2.3 Economic Decision Support

Many expensive decisions happen in the economic sector, where decision support is used to analyze influences to the investment and to minimize the financial risk. Managers want to plan strategies for their companies and have to include all options and events in their calculations. Developing an influence model and probing it with different scenario data may help them to find the optimal solutions. The appropriate methods for risk analysis are taught in management sciences.

2.4 Group Decision Support

Important decisions are hardly made by one person alone. They have to be communicated among a group of experts and evaluated in a common effort. While least applications can accept simultaneous inputs from distributed participants, group decision making could happen also in a meeting room on an overhead screen moderated by one person. Recent developments introduce web-based software that may be accessed with any web browser.

3 Short Introduction to Decision Theory

Before looking at the different decision analysis applications, some terms and methods need to be clarified in order to understand their functionality. This chapter shows different methods to build a decision structure defining a specific problem and to find a solution with the resulting model. There is much more to learn, but this compact introduction into theory should provide enough knowledge for understanding the following software review.
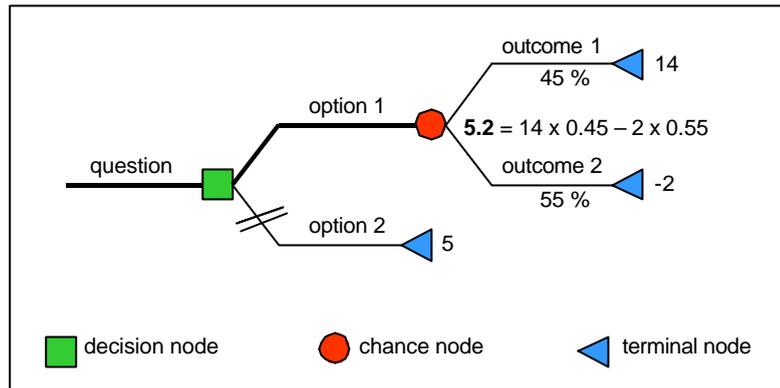
3.1 Decision Trees

To analyze a complex problem it has to be disaggregated into smaller components. That may be smaller decisions as well as uncertain influences. A very formal and traditional approach is the construction of a decision tree that gives a comprehensive visualization of all decision parts. Almost all reviewed applications are based on this important analysis method or on its recent descendants.

The tree starts with the basic question and branches usually lead to the different options. These may branch again into additional alternatives or uncertain events, which can be viewed also as influencing factors. If alternatives or events are not further divided, they end with a terminal node representing a certain event and decision combination that has to be rated. Sometimes an additional logic node is used to include conditional branches into the tree.
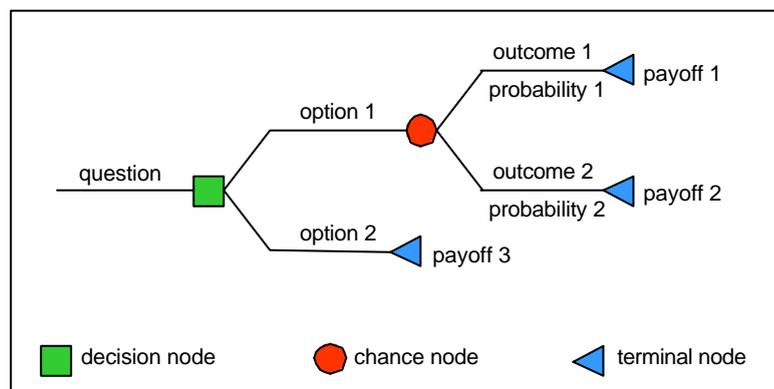
A simple decision tree.

The picture above shows a simple decision tree with only two options and one event with two possible outcomes. While the geometric forms have the same meaning throughout all applications, their colours are not standardized. All outcomes are tightly coupled with their probabilities that must sum up to 100 percent at the connecting chance node. The right-most nodes terminate the chain of events and assign a payoff. For a better understanding of this structure, some values need to be inserted in order to view the results.

Computed result from a decision tree

While time flows from left to right, the results have to be calculated backwards starting with the terminal nodes. Because the first outcome with a probability of 45 percent would be the best case to expect, it is rated with 14 points. Outcome 2 instead is more probable but the worst thing that could happen and therefore rated with a -2. The value of option 2 without any following events lies somewhere between both outcomes and gets a 5. In this process, the rating must be independent from any probabilities.

For every chance node, a value has to be calculated from their weighed inputs. All assigned values have to be multiplied with their weights before they are summed up at the connecting node. In the shown example, the result of 5.2 is slightly higher than the value of option 2. Therefore, it is more advisable to choose option 1 in favour of option 2 even if it has a possible drawback. The decision for option 1 is marked with a bold path in the picture while the defeated alternative has been crossed out.

More examples of classical decision trees are shown at the reviews of DATA Professional (see page 10) and PrecisionTree (see page 15).

3.2 Influence Diagrams

Another approach for modelling offers the recent influence diagrams reducing a complex decision to a few shapes and lines. On first sight, they seem to be much simpler than decision trees but they might hide a great amount of data and conditions behind the scenes. These diagrams are often used to brainstorm a preliminary structure before they are finally converted into decision trees. However, their extended possibilities forbid decision trees to be transformed back into influence diagrams.
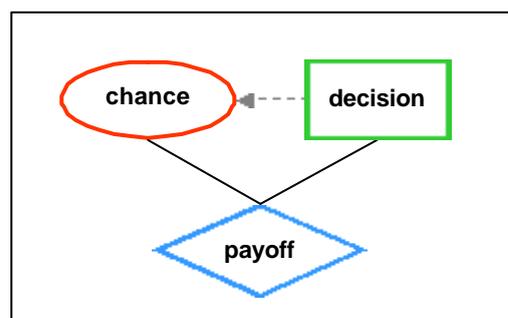
A simple influence diagram

Most nodes are similar to these from the decision trees. The oval node represents a chance event and influences the decision node (rectangle) and the payoff node (diamond). While the diagram may have any number of events and decision nodes, it should have only one payoff node unless a complex formula has to be calculated. All alternatives and outcomes are assigned internally with dialog windows and usually not visible. Arcs between the nodes may contain different forms of influence depending on the connected node types. The arc in dotted grey drawn between the decision and the chance node indicates a probabilistic influence, while the plain black arcs mean a structural relationship.

While influence diagrams are excellent for clearly presenting the relationship between events and the general structure of a problem, decision trees are able to visualize more details in an extensive branching structure. Therefore, some applications like DATA Professional or PrecisionTree use these diagrams as the first stage in decision tree development. While other programs still use tree structures in underlying parts (see DecisionPro on page 18), a few renounce them completely in favour of advanced influence diagrams (see Analytica on page 13).

3.3 Simple Multi-Attribute Rating Technique (SMART)

This decision method assists with a structure evolved from decision trees that is called a value tree. It could be seen as a subset of them with all payoffs set to 1 and a greater flexibility in probability weighing. The change nodes branch not in possible events anymore but in influencing criteria instead. These might be further divided into less important subcriteria, while all alternatives have to be placed at the lowest tree level. An example of a value tree for book selection is shown on page 13.

Assigning weights becomes much easier because any values beyond the usual range of 0 to 1 may be used. The alternatives can now be rated in the natural scales of the criteria (i.e. speed, size, profit). A normalization process sets the lowest criterion weight to 0 and the highest to 1, while the values between are scaled with a determined function into this range. Though this rating method is certainly a great improvement, it is still difficult sometimes to find appropriate values for the criteria.

3.4 Analytical Hierarchy Process (AHP)

It is often easier for decision makers to compare two criteria against one another instead of finding numeric values for the whole set. The Analytical Hierarchy Process makes use of this approach and introduces pairwise comparisons, which result in a semantic rating of options, and attributes. The used descriptions are internally converted into a set of numbers representing the relative priorities of the criteria. Since the AHP is based on value trees too, it is apart from the ranking method analogous to the SMART. It is advisable to divide the criteria into smaller groups of subcriteria, because the rating effort grows with the number of alternatives.

Though this method is a very simple and effective method that allows the synthesis of completely different units, it has an unpleasant disadvantage. Because of the relative rating nature, all alternatives are dependent on each other. Therefore introducing a new option might

suggest great changes in the ranking order, sometimes reversing it completely. This phenomenon is caused by the normalization of the scores on the lowest criteria.

	less important				equal important	more important				
	extremely	much	distinct	some		some	distinct	much	extremely	
Neighbourhood of expressway is…										…than neighbourhood of railway.
Neighbourhood of airport is…										…than neighbourhood of station.
…										…
	1/9	1/7	1/5	1/3	1	3	5	7	9	

This comparison table shows exemplarily how the relationship of competing alternatives might be rated. Even if the weights could be interrelated to guess the factor between criteria A and C automatically by multiplying the rating of A compared to B with the weight between B and C, this is usually not done. Instead, these calculations are used to control the user's model and to indicate occurring differences above a determined limit.

3.5 Sensitivity Analysis

A decision maker might be very interested to know the consequences of varied weights after he gets the first results from his model. Some influence could have been underestimated or a slight variation in one criteria weight could lead to a completely different decision. For that reason, almost all decision analysis tools come with a sensitivity analysis to explore the model further by probing the criteria weights. Some tools offer simultaneous change of two or more values or even the usage of nonlinear functions.
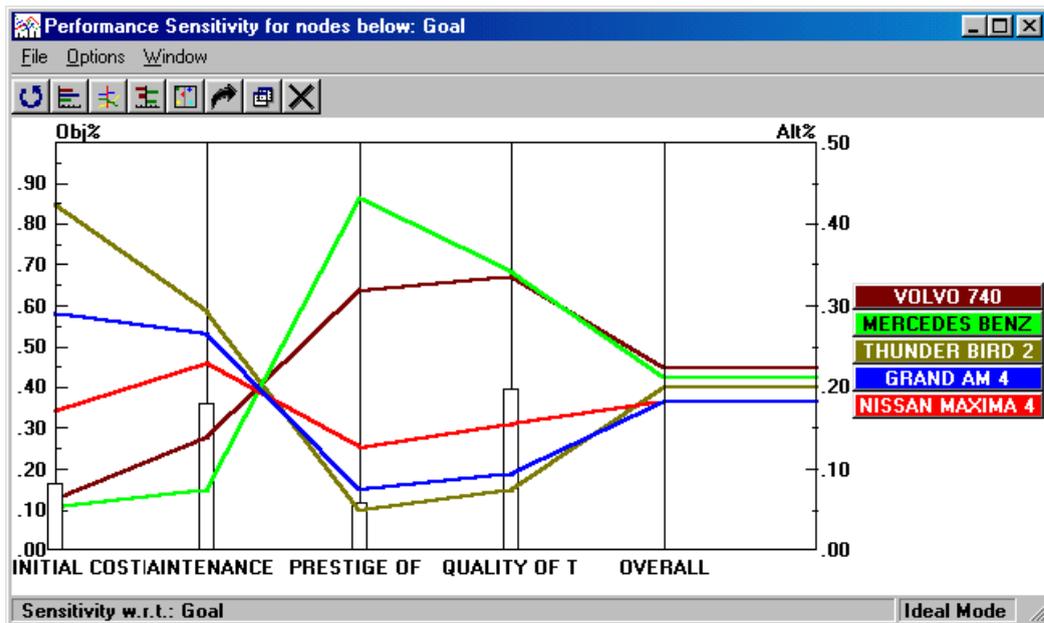
Dynamic sensitivity analysis on four weights with Expert Choice 2000

The above graph shows a dynamic sensitivity analysis for the car purchase decision displayed at the ExpertChoice 2000 review on page 15. While the coloured lines connect all weighed criteria of every alternative, the white bars represent the influence of the criteria on the result. On the right-hand side, the alternatives are ordered by their computed ranking. If a value is changed by resizing the associated bar, all results are immediately recalculated and the ranking is readjusted.

4 Decision Support Software

This chapter provides a selection of very different applications to take an insight into the possibilities of decision support with decision analysis software. Some of the programs emphasize the rating methods while others concentrate on the problem structure. However, all of them give the user a deeper insight into the background of his decisions.

All described applications have been tested with Windows 98 and should therefore be compatible with all newer versions of the Windows operating system. The tested packages are available as trial versions with limitations in time or complexity.

4.1 Excel without any add-ins or links

While many of the following programs use Excel for different purposes, it may also be possible to use Excel alone for decision problems. Because this complex spreadsheet application is coupled with the programming language Visual Basic, almost anything could be done with it.

In contrast to the other decision tools, Excel does not support the graphic construction of decision trees or influence diagrams and sensitivity analysis has to be reproduced with the graph functions of Excel. Simple connections and conditions between data cells may easily be created with standard Excel formulas, while relationships that are more complicated have to be programmed with custom Visual Basic functions. Of course, the structure would be visible to the developer alone, while other users of the solution could only watch interacting data fields without getting the whole picture.

Excel allows the distinct structuring of large data arrays and is therefore an ideal interface for input even if it is not used for decision structuring itself. Recent Excel versions support the data import from external databases and with conditional formatting, the user may be pointed to critical spots. If a graphic representation of the model is not necessary, Excel may be sufficient for decision support.

4.2 DATA Professional 6

Influence diagrams are in DATA only used as a preliminary stage of decision trees that are the foundation for this program. Though this program is originally aimed at the healthcare sector for which it provides special functions, it may be used for many more applications.

By standard, DATA starts with decision tree construction but the work mode may be changed to develop influence diagrams with underlying tree structures. Trees are drawn in the main window, where a roll back function can be used to compute the

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values along the branches and show them. No editing can be done while this function is active so that no real-time calculation may happen. The user inserts new branches with a double click, while deleting nodes is only possible by beginning from the right-hand side.

Variables and calculations ease the automatic distribution of values throughout the whole tree, but sometimes they may not be sufficient to control the whole structure. Complex problems may result in very large trees and the overview may be lost. This effect can be avoided with the use of cloned trees. Parts that occur repeatedly on many different locations may be cut out and linked to a master tree instead. If payoffs and probabilities are defined as variables, they can be altered at the links of the clone trees.

The professional version offers additional building of user interfaces for decision models and uses a special format that can only be read with a separate tool but not be changed anymore. With another plug-in for DATA professional, it is possible to prepare decision front ends in Excel or HTML.
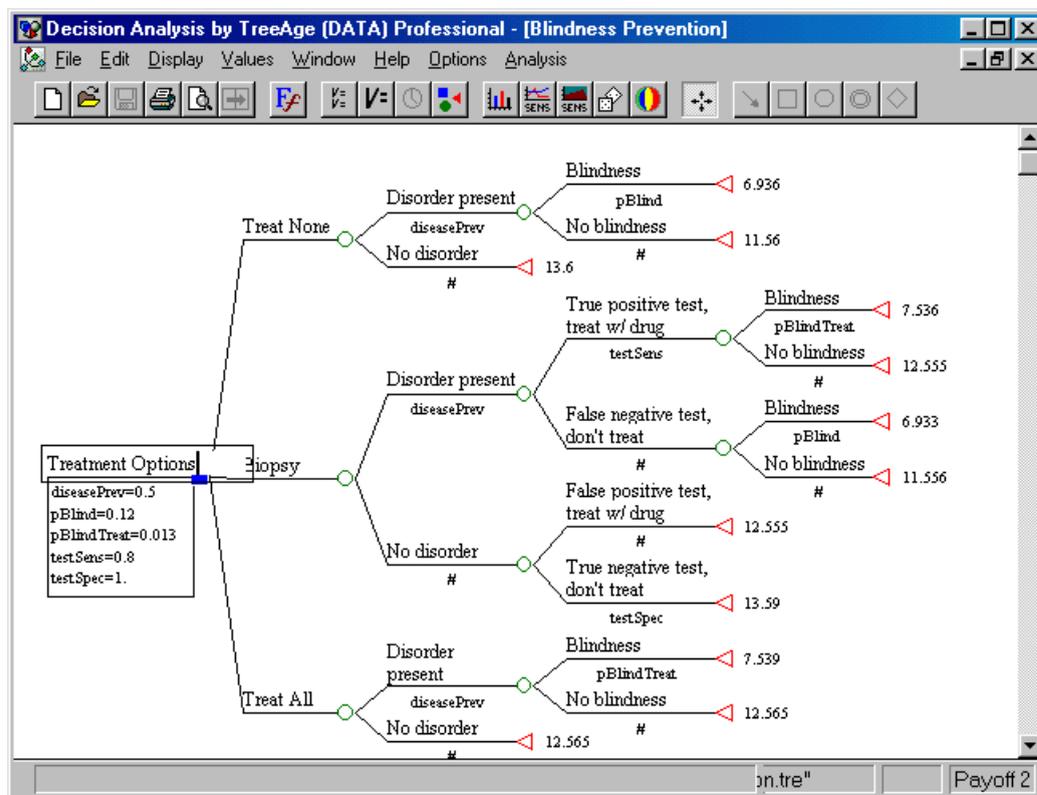
Medical treatment decision in DATA Professional using five variables.

4.3 Analytica 2.0

Though the models from Analytica are very coloured and use some strange shapes, they are still influence diagrams. All relationships are managed without any decision trees. The nodes offer many advanced functions and conditions instead. Like in any other modelling tool, the influence weighing with AHP or SMART is not supported.

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The user is able to manage complex relationships by dividing large diagrams into levels of smaller ones that are linked to their predecessors. Small user interfaces may be created by the use of input and output nodes that connect the diagrams with a custom dialog window.

While the usual data linking to other Windows applications is possible, some features like database access or model protection are available in the enterprise version of Analytica only.

Analytica comes with many mathematical functions, which can be fully utilized by a user with economic knowledge only. This application may be used to build a decision support system but it seems to be more appropriate for complex economic analysis.
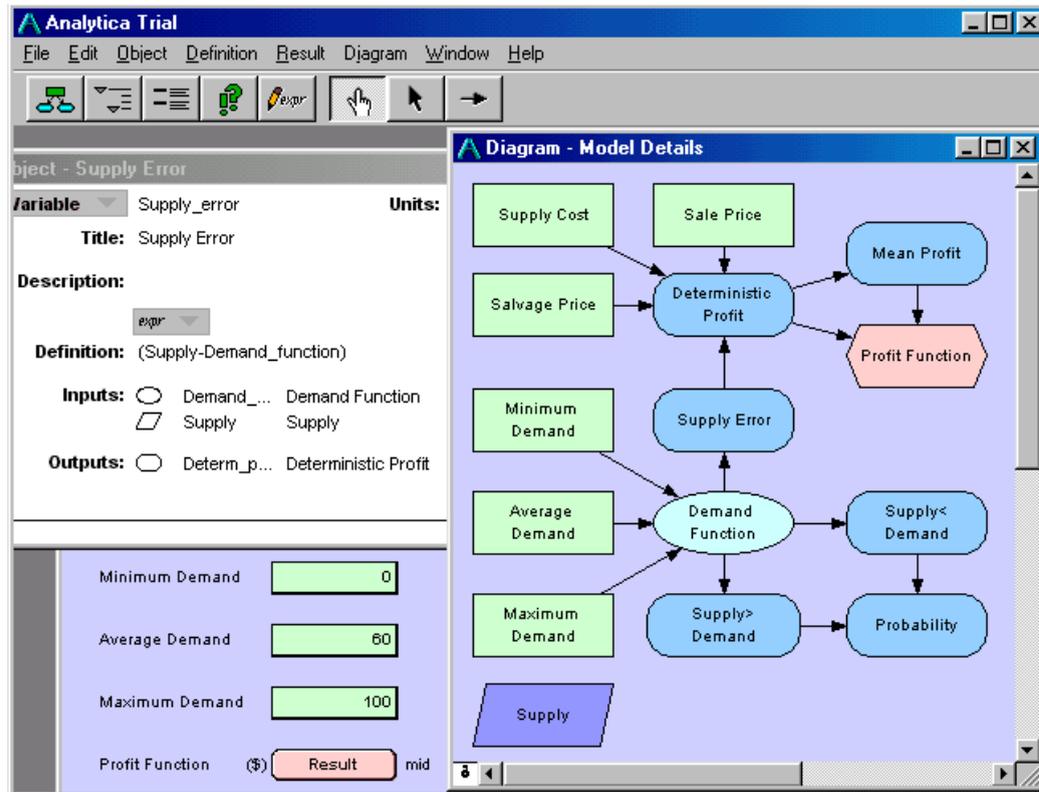
A economic scenario constructed with Analytica

4.4 PrecisionTree 1.0 Professional for Excel

While all other described applications are standalone versions, this tool is tightly bound to Microsoft Excel as an add-in. All decision trees or influence diagrams are drawn directly into the spreadsheet. The program inserts a new toolbar and a new menu with the same functionality. It reuses Excel functions to gather data with dialog windows and small tables as well as to visualize sensitivity analysis results with complex graphs.

All value modifications propagate in real-time through the tree structure and adjust the results, but the user himself has to pay attention that all probabilities sum up to one at every chance node. The optimal scenario is marked with TRUE labels along the branches, while the policy suggestion function additionally displays a reduced tree with the optimum path highlighted.

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Of course, usual links to a spreadsheet cells are possible, but a connection to an external database is not implemented. A dynamic sensitivity analysis cannot be offered because of the static nature of the Excel graph functions. Though this add-in relies heavily on another application for input and output infrastructure, it is not the cheapest one of this review.
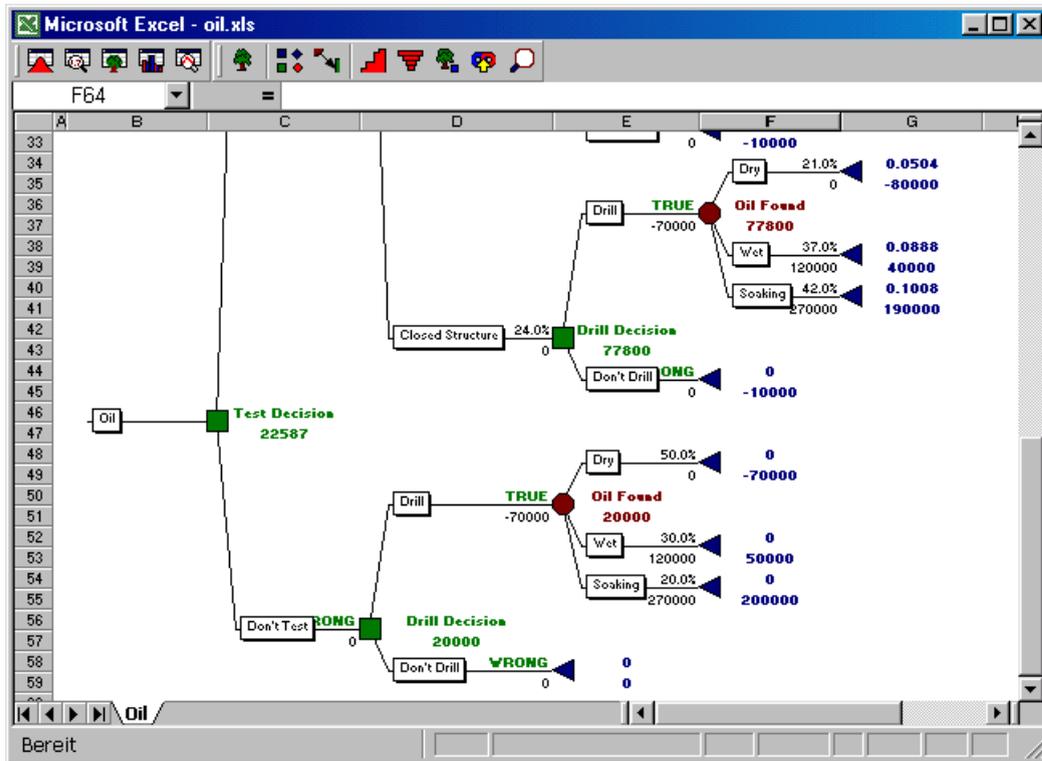
Complex tree structure for oil-drilling decision in Excel spreadsheet.

4.5 Expert Choice 2000

This program is built especially around the Analytical Hierarchy Process (AHP) because the inventor of this methodology is directly involved in the application development. It has no modelling capabilities with decision trees or influence diagrams but concentrates exclusively on the criteria structure.

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The construction of the criteria hierarchy is done in the explorer view (the largest section in the depicted window) or in a very simple graphical way, where the criteria can be grouped into boxes. A classical tree view is only available for printing. After the user has decided about the structure of his decision, he has to compare all listed alternatives in respect to every lowest criterion and all criteria in respect to their including top criterion. For that purpose, he can choose to make numeric, semantic or graphic relations or to assign the weights by directly typing them in.

While browsing through the explorer view, the alternatives are ranked to the selected criterion. Every criterion might be dragged at anytime into another group or to the top level, but afterwards the user has to compare the moved factor against all others in the new group.

Expert Choice offers a dynamic sensitivity analysis that is propagated to four graphs simultaneously. As described and depicted on page 8, the top criteria may be varied to test their influence on the outcome.

Automatic links to other applications are not supported, but data tables may be transferred between Excel and Expert Choice with cut-and-paste. The program seems to be a bit unstable and quits sometimes with a crash.
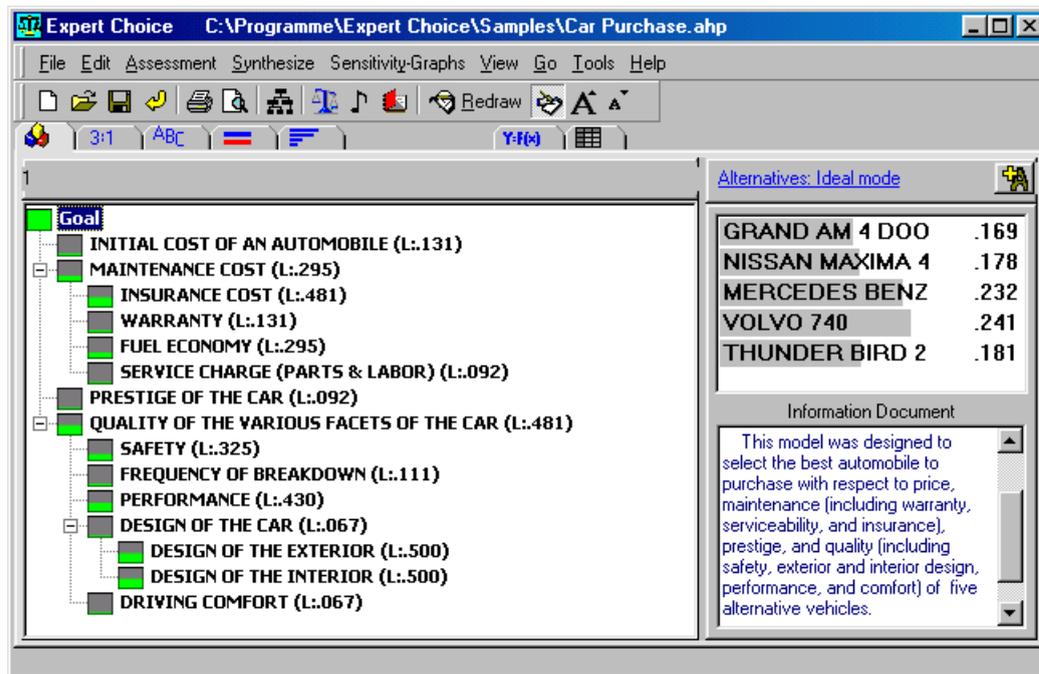
4.6 Criterium DecisionPlus 3.0

In contrast to all other applications, this tool starts with a brainstorming session. The user has to collect his preliminary decision criteria and group them graphically around a central goal while all alternatives ought to be listed in a separate column. To reject unimportant criteria they can be dragged into a trashcan. This process is similar to the creation of an influence diagram and cannot be reverted after the conversion to a decision hierarchy too. This brainstorming might also be skipped to construct the hierarchy directly.

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           techsupport@infoharvest.com

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Instead of placing the main alternatives at the first branching level as in the classic decision trees, this program puts them at the lowest level of a vertical hierarchy and connects them to all criteria in the proceeding level. This value tree is owed to the AHP or SMART rating methods, which the user may switch at any time. In the decision depicted below the user has to rate three books on nine detailed criteria, which are classified by three main criteria. All in all this sums up to 36 (3 x 9 + 3 x 3 + 3) relationships that have to be weighed.

All rating of the connections is done in one single dialog where the user may choose from prepared scales or may define custom scales. With additional rules, the rating can be controlled for defined conditions. Sadly, in the tested version (3.0.4) the graphical sliders do nothing more than assigning the highest value instead of constantly changing it. While it should be possible to use uncertainty functions for the values, the program quits this try with a crash. There seems to be no option to interact with external spreadsheet applications, but a table for the decision scores is offered instead.
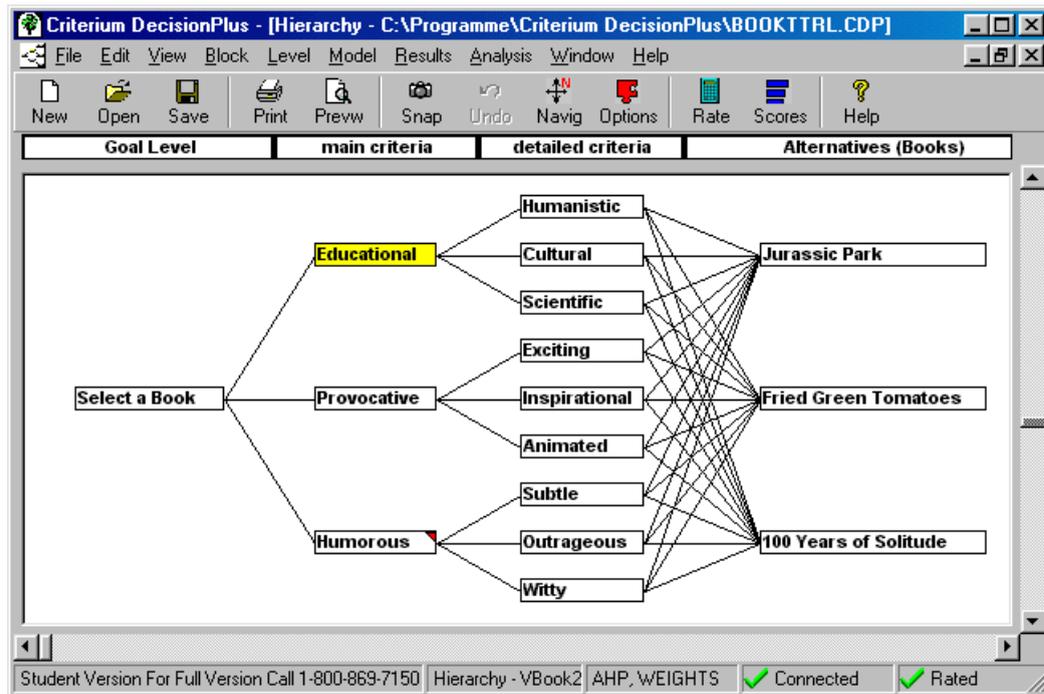
Value tree for AHP or SMART to find the optimal book (Educational selected)
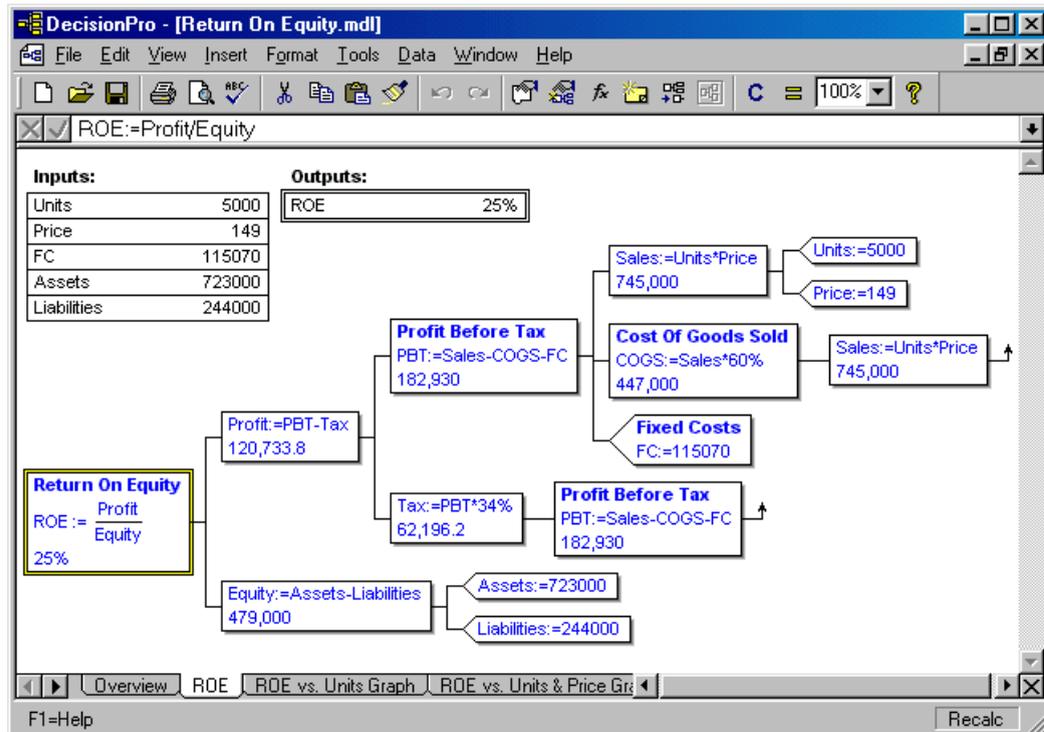
4.7 DecisionPro 4.0

The extensive functionality and its own programming language make DecisionPro one of the most powerful applications, where decision support is only a fraction. Some other features are statistical analysis, linear optimization, financial mathematics and even small expert systems. Almost all possible formulas and conditions can be constructed as hierarchical tree structures with decision trees as special case. The used equations for the single parts are very similar to these in spreadsheet cells.

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Trees are not drawn by the user but arise from his typed definitions. For a better overview, complex trees can be spread over many worksheets and connected at different locations. Variables may be organized in input tables for easier user access and supplied with input nodes to the different locations in the tree. An output table presents the resulting values. Both table types may be created automatically from the definition of the appropriate nodes. The integrated programming language supports the construction of simple user dialogs.

Though links to and from other applications are possible, they are not needed very often, because this program provides most spreadsheet functionality by itself. Data can be imported from external databases or even web pages. It is possible to fetch documents from the web and parse them for valuable information. A special web edition allows web site visitors to access models remotely.

Complex formula in DecisionPro

4.8 Decision Programming Language (DPL) 5.0

While this software offers a powerful programming language, the graphical modelling of decision structures is possible too. Influence diagrams are directly drawn by the user, but decision trees are mainly used in underlying structures and are typically constructed with typed input. The main windows may be parted to show a parallel view of the diagram and the main tree parts but most of the tree structures still have to be accessed indirectly.

Similar to a decision node a strategy table defines different scenarios to be synchronous analysed. All influencing factors are then classified by their importance for the available alternatives. Solved decisions can be viewed in a policy tree that highlights the chosen path.

Links to other Windows applications are possible to transfer data, but a spreadsheet from Excel or Lotus can even be converted into an influence diagram considering all connections between the cells.

This tool with its extensive programming and construction possibilities is not only very power-ful, but also very expensive for commercial use. It is aimed to solve very large decision analysis problems in reasonable time.
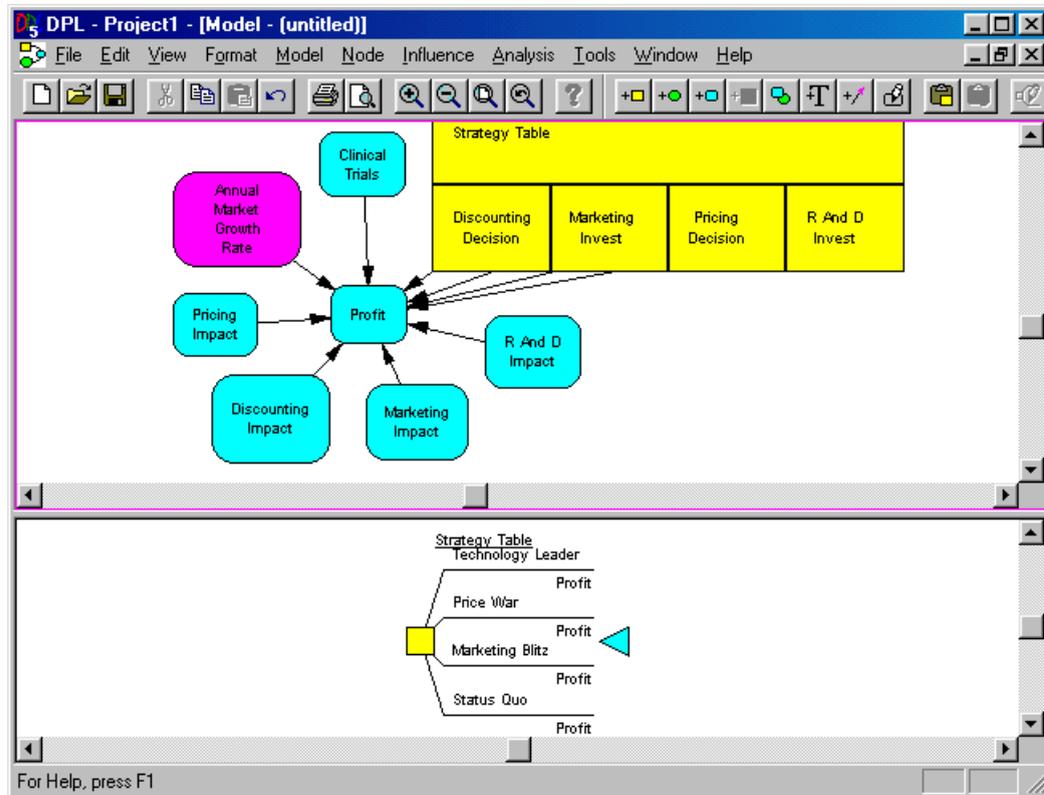
Parallel view of influence diagram and associated decision tree in DPL

5 Decision Support Software

All the modelling applications (Analytica, DATA, DecisionPro, DPL and PrecisionTree) that are able to manage data in spreadsheets or exchange it with external programs may not exclusively be used for decision support but monitoring purposes too. Alternative options can be viewed as competing scenarios that are influenced by certain factors instead of uncertain events. If the deviation from determined values is inserted as payoff at the tree nodes, the result of the nodes can be minimized instead of maximizing it to find the most probable scenario.

All payoff data may be read from an external spreadsheet where it is arranged in tables for a better overview. The results may even be fed back into a spreadsheet application to create custom graphs or reports that are not already offered by the decision analysis software.

Distribution of the moel might be done with the exchange of proprietary files but would require that all receivers have access to the appropriate software. Another more common format is more advisable. A simple user interface has to be constructed that allows use of the decision structure and limited data input but no erroneous changes.

Even if the most expensive software might include all needed functionality and a lot more, it may be possible to achieve success easier with a much cheaper application. However, only a few advanced applications support the creation of user interfaces and are able to protect the underlying structure from any changes.

It is not known if monitoring with decision support software has been realized somewhere yet but the idea of including supervised data values should be evaluated further with a real monitoring model, because the usability of all applications can only then completely be estimated. Even the whole monitoring model itself could be developed with the aid of decision analysis because all impact factors could be probed further with sensitivity analysis and other methods.

6 References

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Analytica Tutorial, 11/2001, 220 pages
http://www.lumina.com/dlana/tutorial.pdf

Expert Choice Manual, 06/2002, 111 pages
(included in Software Package, see below)

Criterium DecisionPlus 2.0 User's Guide and Tutorial, 03/1997, 94 pages
http://www.infoharvest.com/download/cdp20tut.exe2

DATA 4.0 / Pro User's Manual, 08/2001, 566 pages
http://www.treeage.com/files/DATA-Pro-40-Manual.pdf

Decision Programming Language (DPL) General Tutorial, 06/1999, 111 pages
http://www.adainc.com (website recently not available)

DecisionPro 4.0 Online Manual
http://www.vanguardsw.com/DpHelp/Dph00003.htm

Precision Tree User's Guide, 07/2000, 227 pages
http://www.palisade.com/downloads/installcoderequired/dts45manual.exe

Trial Versions

Analytica 2.0 (30 days, fully functional)
http://www.lumina.com/dlana/setupana.exe

Criterium DecisionPlus 3.0
http://www.infoharvest.com/infoharv/CDPFreedownloadsnow.htm

DATA Professional 6 (21 days, 35 nodes)
http://server.treeage.com/demos/downloadpro.htm

Decision Programming Language (DPL) 5.0
http://www.adainc.com (website recently not available)

DecisionPro 4.0 (no printing or saving)
http://www.vanguardsw.com/decisionpro/download.htm

Expert Choice 2000
http://www.expertchoice.com/software/individualtrialreg.htm

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Web based decision support

Consumer Purchase Decision Aid
http://www.psych.upenn.edu/~baron/consumer1.htm

Assistum Examples
http://www.assistum.com/2002/products/examples/

Software Comparison Table

	Analytica 2.0	Criterium DecisionPlus 3.0.4	DATA 4.0	Decision Pro 4.0	DPL 5.0	Expert Choice 2000	PrecisionTree 1.0
decision trees		-	x	x			x
influence diagrams	x	-	x				x
AHP (Analytical Hierarchy Process)	-	x	-	-	-	x	-
SMART (Simple MultiAttribute Rating Technique)	-	x	-	-	-	-	-
sensitivity analysis	x	x	x	x	x	x	x
undo levels		1	10				
two-way sensitivity analysis		-	x				x
multiple references (links)	x	-	x	x	x	-	x
links to spreadsheet cells	x	-	x	x	x	-	x
regular pricing	$1044	$595	$695	$495	$1500	contact	£399
download only	$995		-$20				£384
shipping charge			+$52	+$39			