Chapter 29
Multiple Criteria Decision Analysis Software

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Abstract We provide an updated overview of the state of multiple criteria decision support software. Many methods and approaches have been proposed in the literature to handle multiple criteria decision analysis, and there is an abundance of software that implements or supports many of these approaches. Our review is structured around several decision considerations when searching for appropriate available software.

Keywords Multiple criteria decision analysis software • Decision support • Software package

29.1 Introduction

Multiple criteria decision models generally do not possess a mathematically well-defined optimum solution and thus the best the decision maker (DM) can do is to find a satisfactory compromise solution from among the efficient (non-dominated) solutions. Unless an explicit utility function representing the preferences of the DM is known a priori, interactive solution techniques are most appropriate to identify the preferred solution or perhaps a manageable set of desirable compromise solutions.

An abundance of multiple criteria decision analysis (MCDA) methods have been proposed in the literature, most of which require substantial amounts of computation. Many software packages have been developed to implement all or parts of these methods. This MCDA software covers various stages of the decision making process, from problem exploration and structuring to ascertaining the DM's preferences and identifying a most preferred compromise solution. Many business

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users, however, find it difficult to identify and choose an appropriate software package for their specific problem situation. The primary objective of this chapter is to provide an overview of commercially or otherwise readily available MCDA software and to offer users a practical guide on selecting the appropriate tools for their decision problems at hand.

In the following section, we summarize and categorize available MCDA software based on various decision-problem considerations. Such considerations include the type and characteristics of the decision problem to be resolved, the decision context, and the technology platform required by the software. In Sect. 29.3 of this chapter we then present more detailed reviews of each software package in alphabetical order. Finally, in Sect. 29.4, we offer some concluding observations.

29.2 General Overview of Available MCDA Software

Decision analysis software can assist DMs at various stages of the decision-making process, including problem exploration and formulation, identification of decision alternatives and solution constraints, structuring of preferences, and tradeoff judgments. Many commercially available, general decision analysis software packages have been included in biennial decision analysis software surveys in *OR/MS Today*, the first one published in 1993 [9]. The 2012 survey [53] included 47 decision analysis packages, some of which can be considered MCDA software and are also covered in our chapter. While specifically focusing on MCDA software, our review includes not only commercially marketed packages, but also software that has been developed at academic institutions for research purposes and is made available to the broader community, usually free of charge or for a nominal fee. Commercial packages may sell for hundreds or even thousands of dollars (though some vendors give educational discounts) and usually have dedicated websites and sophisticated marketing literature and may come with training courses and technical support. Software developed not-for-profit by academics usually comes without support and may have only limited documentation.

In order to provide some practical support for choosing the most appropriate software for a specific decision situation, we present a summary of MCDA software covered in this chapter, structured around the following considerations: the characteristics of the decision problem (viz. finite set of alternatives versus infinite options that can be defined by mathematical functions), the MCDA method(s) implemented by the software, the type of decision problem (viz. single DM versus group decision making), and the technology platform(s) supported by the software.

29.2.1 MADA Versus MOO Software

The first selection consideration is based on the characteristics of the decision problem formulation. MCDA normally involves the DM to choose a solution from

the set of available alternatives, which can be finite or infinite [23]. Thus, MCDA problems can be roughly divided into two main types, viz. multiple attribute decision analysis (MADA) problems and multiple objective optimization (MOO) problems. In MADA problems, the DM must choose from among a finite number of *explicitly* identified alternatives, characterized by multiple attributes, where these attributes define the decision criteria. An example would be buying a new car and choosing among the various models available, characterized by attributes such as size, engine power, price, fuel consumption, etc. In contrast, MOO deals with problems where the alternatives are only *implicitly* known. In MOO problems, the decision criteria are expressed in the form of mathematical objective functions that are to be optimized. The argument vectors of the objective functions constitute the decision variables and can take on an infinite number of values within certain constraints. An example would be developing a new engine for an automobile manufacturer, where the decision criteria may include things like maximum power, fuel consumption, cost, etc., described by functions of the decision variables such as displacement capacity, compression rate, material used, etc. MOO models may involve linear or nonlinear objective functions and constraints, and may have continuous or integer decision variables. MOO software typically implements various optimization algorithms, such as linear programming, nonlinear programming, generic algorithms, meta-heuristics, etc. Table 29.1 categorizes the reviewed software packages according to these two types of problems.

29.2.2 MCDA Methods Implemented

The second selection consideration is the MCDA method implemented by the software. Corresponding to the two types of MCDA problem formulations, methods can be categorized into multiple criteria design methods and multiple criteria evaluation methods [13].

Multiple criteria design methods are intended to solve MOO problems, sometimes also referred to as multiple criteria design problems or continuous multiple criteria problems. A very large number of optimization methods of this type have been proposed, where each individual method is designed to solve a specific or a more generic type of MOO problem. Different MOO software generally implements different MOO methods.

Multiple criteria evaluation methods are intended to solve MADA problems, sometimes also called multi-criteria evaluation or selection problems. Brief descriptions of multiple criteria evaluation methods implemented by the software surveyed in this chapter are given in Table 29.2. More detailed descriptions of many of these methods can be found in earlier chapters in this book.

Table 29.3 shows which software packages implement methods from Table 29.2. Not all software packages explicitly state the method(s) employed, and often this information needs to be derived from their technical description. Some software packages implement multiple methods and are listed multiple times in Table 29.3.

Table 29.1 MADA and MOO software

Software for Multiple Attribute Decision Analysis (MADA)	1000Minds	4eMka2/jMAF	Accord
	CDP	DecideIT	Decision Explorer®
	Decision Desktop/Diviz	Decision Lab/Visual PROMETHEE	DPL 8
	D-Sight	ELCTRE III-IV	ELECTRE TRI
	ELECTRE IS	Equity	ESY
	Expert Choice	FuzzME	GeNIe-Smile
	HIPRE 3+	HIVIEW	IDS
	INPRE and ComPAIRS	IRIS (VIP)	JAMM/jRank
	Logical Decision	MakeIt Rational	Market Expert Markex
	MindDecider	MINORA	M-MACBETH/WISED
	MOIRA, MORIA Plus	NAIADE	OnBalance
	Prime Decisions	Priority Mapper	Prism decision System
	RICH Decision	Rubis	SANNA
	MC-SDSS for ArcGIS	TransparentChoice	Triptych
	UTA Plus	Very Good Choice	VIP Analysis
	VISA	Visual UTA	WINGDSS
	WINPRE		
Software for Multiple Objective Optimization (MOO)	ACADEA	Analytic Optimizer	APOGEE
	BENSOLVE	FGM	GUIMOO
	iMOLPe	IND-NIMBUS	interalg
	iSight	modeFrontier	Optimus
	ParadisEO-MOEO	Pareto Front Viewer	RGDB
	SOLVEX	TRIMAP	Visual Market

Table 29.2 Multiple criteria evaluation methods

AHP	AHP (*Analytic Hierarchy Process*) [61] provides a systematic procedure to model MADA problems as multilevel hierarchies, with the overall decision objective at the top of the hierarchy, the decision alternatives (options) at the bottom of the hierarchy, and the decision criteria (attributes) in the middle levels, possible with sub-criteria. AHP derives ratio scales from pair-wise comparisons of the elements at each level (with respect to elements at a higher level), which are then combined into overall preference weights for the alternatives. Preference consistency values are calculated.
Bayesian Analysis	Bayesian analysis is a statistical decision making approach for utilizing information in the form of possibilities [51]. Based on Bayesian decision theory, it prescribes the optimum alternative as one that maximizes the subjective expected utility. Bayesian analysis is useful in an environment of uncertainty and risk.
Cognitive Mapping	Cognitive mapping is based on *personal construct theory* [36] and has been used to explore and represent the DM's understanding of the relationships among interacting concepts [12]. Cognitive mapping can facilitate the DM in exploring and formulating MADA decision problems, as well as gathering and structuring qualitative data.
DELTA	The DELTA method [16] is based on classical statistical theory to evaluate decision problems using probability and utility intervals for alternatives and consequences when the decision information is imprecise.
DRSA	DRSA (*Dominance-based Rough Sets Approach*) [29, 30] extends original rough set theory to model and exploit the DM's preferences in the form of decision rules.
ELECTRE Family	The ELECTRE (*ELimination Et Choix Traduisant la REalité—Elimination and Choice Expressing Reality*) family of methods is based on the principles of outranking, a concept originated by Roy [57]. The outranking methods are based on multi-attribute utility theory principles, motivated by decision efficiency for pair-wise comparisons of all options. ELECTRE family methods have been applied to choosing, ranking and sorting problems, as well as fuzzy and non-fuzzy outranking relations.
Evidence Reasoning	The Evidence Reasoning approach adopts the principles of *utility theory* and *Dempster-Shafer theory of evidence* [18, 69]. It uses a belief decision matrix [77] to systematically model MADA decision problems under different types of uncertainties, such as objectivity, randomness, and incompleteness.
MACBETH	MACBETH (*Measuring Attractiveness by a Categorical Based Evaluation Technique*) is an interactive approach that requires only qualitative judgments about differences in values to help DMs to quantify the relative attractiveness of options [2]. It derives value scores and criteria weights using additive aggregation modeling.

(continued)

Table 29.2 (continued)

MAUT and MAVT	MAUT (*Multi-attribute Utility Theory*), developed by Keeney and Raiffa [35], uses utility functions to convert raw performance values of alternatives with respect to the decision criteria to a common scale. MAVT (*Multi-attribute value theory*) is a modified version of MAUT [24]. It differs from MAUT in that the aggregated utilities of alternatives are ranked and also recognizes the importance of criteria weights in decision making [13]. MAUT and MAVT constitute a family of methods that focus on the structure of multiple criteria, especially when risks or uncertainties play a significant role in defining and assessing alternatives [23].
PAPRIKA	PAPRIKA (*Potentially All Pairwise RanKings of all possible Alternatives*) [32] involves the DM performing pair-wise value ranking of *undominated* pairs of alternatives. The number of such rankings needed are kept to a minimum by identifying and eliminating implicitly ranked undominated pairs.
PROMETHEE	PROMETHEE (*Preference Ranking Organization METHod for Enrichment Evaluation*) is a popular family of outranking methods, developed by Brans [6]. The PROMETHEE methods provide flexible preference modeling capabilities through powerful interactive sensitivity analysis tools. PROMETHEE family methods have evolved to include partial ranking, complete ranking, ranking based on interval and continuous cases, etc. A visual interactive version (GAIA) was also introduced [5] to enable the DMs to better understand available choices and the impact of decision weights on the rankings.
SMART	SMART (*Simple Multi-attribute Rating Technique*) [73] is a simple form of a multi-attribute utility method. The alternatives are rated directly in the natural scales and the different scales of criteria are converted to a common scale mathematically using a simple value function. The weighted algebraic mean of the utility values associated with the alternative become its ranking value.
UTA	The UTA (*UTilités Additives*) method proposed by Jacquet-Lagrèze and Siskos [34] adopts the principles of MAUT but using a preference disaggregation rather than aggregation approach.

Table 29.3 Software by method implemented

Method	Software packages		
AHP	CDP Expert Choice HIPRE 3+ INPRE and ComPAIRS JAMM/jRank	Logical Decision MakeItRational MindDecider OnBalance Prime Decision	Priority Map TransparentChoice Triptych WINPRE
Bayesian Analysis	Accord		
Cognitive Mapping	Decision Explorer®	MindDecider	
DELTA	DecideIT		
DRSA	4eMka2/jMAF		
ELECTRE Family	ELECCALCELECTREIS	ELECTRE TRI IRIS (VIP)	SANNA Very Good Choice
Evidence Reasoning	IDS		
MACBETH	HIVIEW	M-MACBETH/WISED	
MAUT or MAVT	DPL 8 GeNie&Smile Prime Decision System NAIADE	Equity HiPriority RICH Decision VISA	ESYMOIRA, MORIA Plus MC-DSS for ArcGISWINGDSS
PAPRIKA	1000Minds		
PROMETHEE	Decision Lab/Visual PROMETHEE	D-Sight	SANNA
SMART	CDP HIPRE 3+ JAMM/jRANK	Logical decision Prime Decision	Priority Map WINPRE
UTA	Decision Desktop/Diviz Markex	VIP Analysis MINORA	UTA Plus

Table 29.4 Software with group decision support capabilities

Package	Specific GDSS	General and group	Specific version/add-in module
1000Minds		√	
Accord		√	
Decision Explorer®		√	
Decision Lab/Visual PROMETHEE		√	
D-Sight		√	Requires multi-actor plug-in
Equity3		√	Requires Catalyze Decision Conferencing Services
Expert Choice		√	Web-based Version
HIPRE 3+		√	Group-Link Version
HIVIEW3		√	Requires Catalyze Decision Conferencing Services
Logical Decision		√	LDW for Group Version
MindDecider		√	Group Version
OnBalance		√	
Prism GDSS	√		
TransparentChoice		√	
WINGDSS	√		

29.2.3 Group Decision Support

Group decision-making is a central concern in organizational settings since many important decisions are taken collectively by groups of people. The complexity of MCDA is greatly increased in the group setting. MCDA group decision support involves not only problem definition, criteria identification and prioritization, and individual preference elicitation, but also requires aggregating different individual preferences on a given set of alternatives into group judgments [38]. Table 29.4 lists software packages that provide group decision support capabilities. Some of the software packages are specific group decision support systems (GDSS), while others support both individual and group decision-making. Also, some of the packages provide group decision support only in specific versions or add-on modules.

29.2.4 Platform Supported

The computing environment supported by a software package is an important software selection criterion. If the desired software does not run on the user's currently

available platform, extra updating costs may have to be taken into consideration. Also, some users may prefer a web-based application rather than a standalone package, while others may not want to host the data on a server and prefer a desktop version. One of the surveyed packages offers a software-as-a-service (SaaS) version. Some mobile-based MCDA applications are available, though they are not included in this survey, as currently these applications seem to be primarily intended for making personal decisions only. In the future, more mobile applications may be developed. Table 29.5 presents a summary of platforms supported by the surveyed software packages. Most MCDA packages were developed for Microsoft Windows based personal computers. Several software packages, mostly MOO software, are Microsoft Excel add-ons or Matlab solvers. There are some software packages exclusively implemented as web applications, and some with a web application version. There is also software implemented as plug-ins, or subroutine libraries. Two of the reviewed software packages are in fact subsystems of other packages. One software package requires a desktop client and a MySQL server. There is also an open source software package available.

29.3 Software Review

29.3.1 1000Minds

http://www.1000minds.com. 1000Minds implements the PAPRIKA (*Potentially All Pairwise RanKings of all possible Alternatives*) method [32], which involves the DM performing pair-wise value rankings of *undominated* pairs of alternatives. PAPRIKA keeps the number of such rankings needed to a minimum by identifying and eliminating implicitly ranked undominated pairs. 1000Minds prompts users, depending on what they want to do, to follow a simple six-step MCDM process: criteria selection (qualitative or quantitative), alternatives input (optional), pairwise ranking, preference values (derived by 1000Minds), ranked alternatives, and alternatives selection (including value-for-money analysis). Customized group decision-making processes involving potentially large numbers of participants can be created based on six decision activities provided by 1000Minds: decision surveys, online voting, alternatives entry, ranking surveys, categorization surveys, and ranking comparisons. The software supports an unlimited number of alternatives and a maximum of 30 decision criteria. 1000Minds is Internet based, with its servers housed in the USA and New Zealand. A 21-day trial use is available through the website and the software is available for free for unfunded research and study. A 1000Minds software development kit is also available as either a .Net class library or via web services.

Table 29.5 Software platforms

Platform	Software packages	
Windows	4eMka2/jMAF	JAMM/jRank
	Accord	Logical Decision
	Analytica Optimizer	MakeItRational
	CDP	Market Expert (Markex)
	DecideIT	M-MACBETH
	Decision Explorer®	MindDecider
	Decision Lab/Visual PROMETHEE	MINORA
	DPL 8	ModeFrontier
	D-Sight	MOIRA, and MORIA
	ELCTRE III-IV	Optimus
	ELECTRE TRI	OnBalance
	ELECTREIS	Pareto Front Viewer
	Equity	Plus
	Expert Choice	NAIADE
	FuzzME	Prime Decisions
	GUIMOO	Priority Mapper
	HIPRE 3+	TRIMAP
	HiPriority	UTA Plus
	HIVIEW	VIP Analysis
	IDS	VISA
	iMOLPe	Visual Market
	IND-NIMBUS	Visual UTA
	INPRE and ComPAIRS	WINGDSS
	interalg	WINPRE

Apple Mac	MakeItRational	interalg
Web-based	1000Minds D-Sight Expert Choice FGM GeNIe-Smile HIPRE 3+	IND-NIMBUS MakeItRational Prism Decision System RICH Decision RGDB TransparentChoice
Excel Add-on	SANNA 2009 Triptych Very Good Choice	ACADEA APOGEE
Subsystems	ESY	i-Sight
Plug-ins for d2	IRIS	Rubis
SaaS	Accord	WISED
Unix/Linux	ModeFrontier	interalg
Client–Server	Decision Desktop/Diviz	WISED
Fortran Library	SOLVEX	
Matlab Solver	BENSOLVE	
Open Source	ParadisEO-MOEO	
ArcGIS.net Extension	MC-SDSS for ArcGIS	

29.3.2 4eMka2/jMAF

http://idss.cs.put.poznan.pl/site/70.html. 4eMka2 is an implementation of the *dominance-based rough sets approach* (DRSA) [29, 30]. DRSA extends original rough set theory in the MCDM domain to model and exploit DMs preferences in terms of decision rules, with specific considerations of the characteristics of different types of multiple criteria problems. 4eMka2 system is specifically designed for solving multiple criteria sorting problems, by combining rough set theory with dominance relation to describe rough approximation of decision classes. Decision rules are extracted from a set of already classified examples (prepared by the user), and decision rules are represented in natural language as a set of "if . . . then . . . " statements. The system includes features like data validation, qualitative estimation of the ability of criteria and attributes to approximate the classification of objects, finding the core of criteria and attribute, inducing decision rules using the DOMLEM (minimal cover set of rules) and ALLRULES algorithms, and applying decision rules to reclassify objects with known decisions and to classify new objects. There is no a priori constraint imposed on the size of the decision problems. Rather, the size is said to depend on available memory and affordable computation time. 4eMka2 is Win32-based and free for download. 4eMKa2 is now outdated and has been replaced by jMAF, a Java application based on Eclipse Rich Client Platform UI.

29.3.3 ACADEA

ACADEA is a multi-objective optimization system for performance review of individual faculty in a university [1]. The system considers the aggregate performance of an academic department using the result of individual faculty member evaluations. Objectives are operationalized into criteria in the areas of research output, teaching output, external service, internal service and cost. Data envelopment analysis (DEA) approach is incorporated in the optimization model for efficiency measurement. Implemented as a spreadsheet add-on, the system can be used as an academic policy aid.

29.3.4 Accord

http://www.robustdecisions.com. Accord software is a decision support tool that helps individuals and groups make better decisions with uncertainty. The software integrates three main technologies: Taguchi's method of robust design, product design process, and Bayesian team support (BTS), among which BTS is a patented approach to decision support and the foundation for Accord. BTS is based on

Bayesian decision theory [51, 67]. Given a decision problem, the theory prescribes an optimal decision choice to select the alternative that maximizes the subjective expected utility. BTS extends Bayesian decision theory to integrate the "subjective expectances" from multiple DMs in a group decision-making situation. BTS also incorporates Bayesian methods with expert-based methods to support the decision-making process. BTS includes the following Bayesian analysis methods: subjective expected utility, marginal value of information, and probability of being best (combining preferences from multiple DMs' evaluations). The interface of the software includes four main features: (1) a belief map to provide belief modeling, (2) alternative comparison, (3) criteria used to compare alternatives, and (4) collaboration management of team members. Accord is offered in standalone, enterprise and SaaS versions. Thirty-days free trial is available.

29.3.5 Analytica Optimizer

http://www.lumina.com. Analytica is a family of decision support software that helps people visually create, analyze, and communicate decision models. Its underlying technologies are influence diagrams (visual representation of all essential elements of a decision problem in the form of decisions, uncertainties, and objectives) and Monte Carlo simulation (to evaluate risk and uncertainty). Analytica Optimizer, the highest edition level of Analytica, provides MOO support through its sublicensed solver engines from Frontline Systems.[1] It automatically distinguishes linear programming, quadratic programming or general non-linear programming optimization and seamlessly integrates optimization with all of other Analytica's core features. The optimization engines in Analytica Optimizer have various limits on the number of variables and constraints. For continuous linear programming and quadratic programming problems, there is a limit of 8000 variables and 8000 constraints. For integer or mixed-integer linear or quadratic programming, there is a limit of 2000 variables and 2000 constraints. For general non-linear problems, there is a limit of 500 variables and constraints. Add-on engines can be purchased to eliminate aforementioned limits on problem sizes. Anlytica optimizer is Windows based and is available for a free 30-day trial.

29.3.6 APOGEE

http://www.stat-design.com/Software/Apogee.html. Apogee is the statistical analysis, allocation and optimization engine for Triptych (see Sect. 29.3.59). Apogee works with mathematical functions $Y = f(X)$ created in Excel workbooks, where

[1] http://www.solver.com/about.htm.

X is a statistical variable (as a parameter) and Y is a mathematical function of the parameters (as a response). Apogee then provides statistical capabilities, including sensitivity analysis, Monte Carol Analysis, Allocation, and MOO, for assessing and improving the variation of the responses. Genetic algorithm approach is implemented to provide multi-objective, nonlinear, and global optimization. Unique to this tool is that the optimization approach allows X parameter uncertainty information to be included in the formulation and allows the Y response to be optimized for the mean, standard deviation, and/or probability of non-compliance (PNC) of multiple responses. A 10-day free trial is available.

29.3.7 BENSOLVE

http://ito.mathematik.uni-halle.de/~loehne/index_en_dl.php. BENSOLVE [39] is a free multi-objective linear programming (MOLP) solver in MatLab. It implements Benson's algorithm to solve linear vector optimization problems. The latest version, BENSOLVE-1.1, is available for free download.

29.3.8 Criterium Decision Plus (CDP)

http://www.infoharvest.com/ihroot/index.asp. CDP is a Windows-based visual multiple criteria decision support tool by InfoHarvest Inc. It supports both SMART [25] and AHP [61] methodology. Uncertainty is supported through graphical representation of uniform, triangular, normal, lognormal, and custom distributions for input attributes. CDP models can also be used directly in the freely available Ecosystem management Decision Support (EMDS) system for spatial MCDA decision-making, though CDP still has to be purchased separately. Version CDP 3.0 can support up to 200 alternatives and 500 blocks in total. To accommodate a greater number of alternatives, the *Weighted Decision Object* 3.0 (WDObj) that encapsulates the capability of CDP in an ActiveX (COM) object can be incorporated into the applications. A free CDP 3.0 student version, with all features but restricted model size, is downloadable from the vendor's website. CDP is compatible with Windows 95 to Windows 7, but Windows Vista is not supported.

29.3.9 DecideIT

http://www.preference.nu/site_en/decideit.php. DecideIT is marketed by Preference AB and is designed to integrate various procedures for handling vague and imprecise information in a complex decision situation and probabilistic decision analysis. Originated from MAUT, the tool utilizes the DELTA method [16, 17]

to evaluate decision problems using weight, probability and utility intervals, and qualitative comparisons for criteria, alternatives and consequences. It provides decision trees and influence diagrams (transformed into a corresponding decision tree after evaluation) with criteria hierarchies to model users' decision architecture. Imprecise probabilities and utility value statements are captured through GUI, and results are graphically presented in various ways, e.g., as pair-wise comparison of alternatives. It also provides a graphical overview of the preference ordering among consequences and critical elements of a decision problem. The vendor also claims that "DecideIT provide means for analyzing decisions involving multiple and conflicting objectives and several stakeholders with differing views on the objectives." DecideIT supports 15 alternatives at the root level, 512 consequences per alternative, 1023 nodes per alternative, and 99 decision criteria. The software runs on Windows XP or Windows 7, with Java runtime environment and minimal 512 MB RAM. A trial version of DecideIT is available.

29.3.10 Decision Explorer®

http://www.banxia.com/dexplore. Decision Explorer® by Banxia Software is a Windows-based tool for managing qualitative information that surrounds complex or uncertain situations. The basic technique employed is cognitive mapping, a technique founded on the theory of personal constructs [36]. Decision Explorer® can facilitate group discussion and understanding by means of its visual development of problem issues. In addition to a number of tools to draw cognitive maps, the software provides a large number of analytical tools that assist in evaluating the similarities and differences of sets and in developing and analyzing clusters of information about the problem. The standard licenses are limited to 8000 concepts in its model sizes. The website provides a tutorial, case study, demonstration downloads, and a bibliography of material related to the software or the cognitive mapping method.

29.3.11 Decision Desktop Software (d2)/Diviz

http://www.decision-deck.org/d2/index.html. Decision Desktop Software, or d2, is a rich open source Java software containing several MCDA methods. It was the first software developed by the Decision Deck project, an effort to collaboratively develop open source multiple criteria decision aid software. The d2 allows decentralized evaluations from several experts, whose evaluation results can then be analyzed by a coordinator. Several MCDA methods and utilities plug-ins are bundled within the platform, including IRIS (see Sect. 29.3.31), Rubis, VIP (see Sect. 29.3.55), UTADISGMS and GRIP, and Weighted Sum. The d2 requires a local desktop installation of a client (Java 5 JRE is required) and uses a database to store application data on the server side (version 4.1.x or higher MySQL server is

required). Decision Desktop is currently in a frozen development state due to a lack of developers. Another software under development by the same group is Diviz, currently used by students and researchers from around 15 universities in Europe. Diviz considers MCDA methods as sequences of more elementary algorithms, which can be rebuilt in the software as algorithmic workflows. Currently, there are about 100 algorithmic components available, ranging from outranking methods to value-based methods. The list of components can be viewed at http://www.decision-deck.org/diviz/webServices.html. A java-based Diviz client (which runs on Windows, Linux, or Mac) is required on the user's end. Calculations are done on servers located in France and Luxembourg.

29.3.12 Decision Lab 2000/Visual PROMETHEE

Decision Lab 2000 is an interactive decision support system [28] based on the outranking methods PROMETHEE [7, 8] and GAIA [5]. Sensitivity analyses are generated by using techniques of walking weights, intervals of stability, and the graphical axis of decision, displayed by the GAIA method. The software is also suitable for group decision support, providing profiles of actions and multi-scenario comparisons. The methodology used here requires fewer comparisons from the decision maker than the AHP method; it permits the user to define his own measurement scale. The original download link from its original developer and distributor, Visual Decision Inc. is no longer active. However, a new version of the software, Visual PROMETHEE beta is available for download (http://www.promethee-gaia.net/softwareF.html). Visual PROMETHEE is a Windows (XP, Vista, 7) application. Visual PROMETHEE also includes a PROMap GIS feature that is integrated with Google Maps. Internet connection is required to use the GIS PROMap feature.

29.3.13 DPL 8

http://www.syncopation.com. DPL 8 is a family of software products for decision and risk analysis. Decision modeling is provided through influence diagrams and decision trees. A typical decision tree includes a decision node to model decision alternatives, a chance node to model decision options, and a value node to model decision goals. After running the model, the decision analysis result is presented in the form of a policy tree. In case of a continuous chance node, a Monte Carlo simulation feature can be used to analyze a continuous model. The DPL 8 family includes Direct, Professional, Enterprise, and Portfolio, versions. The entry-level Direct version is a pure Excel add-in, while the other versions offer both an add-in interface and a standalone application interface. While there is no limit to the number of alternatives within a decision model, there is a limit of 1024

attributes for the decision criteria. DPL uses a standard Windows (XP or later) environment. Minimum storage requirement is 25MB of hard disk space, or 70MB for a full installation with all documentations. A demo is available for DPL 8 Direct and Professional. Discounted academic licenses are available for the Direct and Professional versions.

29.3.14 D-Sight

http://www.d-sight.com. D-Sight is relatively new MCDA software based on the PROMETHEE GAIA and utility-based methods. The evaluation criteria are organized through criteria hierarchy trees. The DM's preferences can be modeled through either pair-wise comparisons (PROMETHEE) or utility functions. After the specification of evaluation criteria and preferences, the software ranks and scores the alternatives. D-Sight software solutions are now using scoring scales between 0 and 100. However, D-Sight Desktop offers a PROMETHEE plug-in that displays scores using the -1 $+1$ PROMETHEE scale. A projection of alternatives and criteria (the GAIA plane) allows evaluation of how the alternatives perform with respect to the different criteria as well as how the criteria act as differentiators for alternatives. D-Sight is available as a desktop version or as a Web application. For the desktop version, additional functions can be obtained through D-Sight's plug-ins, such as Maps (free), multi-users plug-in (for group decision making), weights elicitation, and sub-set optimization. The D-Sight Web is a collaborative decision-making platform managing online projects in which people have specific roles, such as project managers, experts, etc. For the desktop version, a Windows-based Java Runtime version 6 or later, and 30MB free disk space are required. Special rates for academics are available, as well as a free 14-day trial version. A permanent free version of D-Sight Web is offered, which is thus not limited in time, but limited to one user account and one project at any time.

29.3.15 ELECTRE III-IV

http://www.lamsade.dauphine.fr/spip.php?article241. ELECTRE III aggregates partial preferences into a fuzzy outranking relation [27, 58]. ELECTRE IV builds several non-fuzzy outranking relations when criteria cannot be weighted. Two complete preorderings are obtained through a "distillation" procedure, either from the fuzzy outranking relation of ELECTRE III, or from the non-fuzzy outranking relations provided by ELECTRE IV. The intersection of these preorderings indicates the most reliable global preferences. A demo version of ELECTRE III-IV is available for download. ELECTRE III-IV runs on Windows.

29.3.16 ELECTRE IS

http://www.lamsade.dauphine.fr/spip.php?article238. ELECTRE IS represents an evolution of the ELECTRE I method [59] and enables the use of pseudo-criteria (criteria with thresholds). Given a finite set of alternatives evaluated on a consistent family of criteria, ELECTRE IS supports the user in the decision process of selecting one alternative or a subset of alternatives. The method consists of two parts: construction of one crisp outranking for modeling the DM's preferences, and exploitation of the graph corresponding to this relation. The subset searched is the kernel of the graph.

29.3.17 ELECTRE TRI

http://www.lamsade.dauphine.fr/spip.php?article244. ELECTRE TRI is a multiple criteria decision-aiding tool designed to deal with sorting problems. This software implements the ELECTRE TRI method that provides two different procedures (pessimistic or optimistic) to assign a finite set of actions to a set of categories corresponding to predefined guidelines [48]. ELECTRE TRI Assistant reduces the cognitive effort required from the DM to elicit the preference parameters by enabling weights to be inferred through a form of regression.

29.3.18 Equity3

http://www.catalyze.co.uk/?id=229. Equity3 is a PC-based MCDA tool originally developed by Catalyze Ltd in association with LSE Enterprise (London School of Economics and Political Science). It aims at helping DMs obtain better value-for-money from their portfolio decisions. Decision models in Equity3 are mostly built to aid the allocation of monetary resources to an investment portfolio. Building on the same methodological framework as HIVIEW3 (see Sect. 29.3.27), Equity3 includes five main model building stages, which are *model construction*, *scoring*, *setting preferences*, *analyzing models*, and *recommendations*. However, the model construction stage in Equity3 is quite different from HIVIEW3: it groups the portfolio of options into logical towers in the model structure. Detailed portfolio analysis in Equity 3 includes efficiency frontiers, affordability and trade-off analysis. Equity3 supports qualitative criteria and group decision making in the same manner as HIVIEW3. A 20 days free trial version is available for download. Educational licensing is also available, but support needs to be purchased separately.

29.3.19 ESY

ESY (*evaluation subsystem*) [52] employs the multi-attribute value theory model to help decision makers make more rational decisions and promote consistency in their decision making throughout all phases of a nuclear emergency. ESY provides decision support not only in the evaluation, but also in the formulation and appraisal of the decision strategies. It is one of the three distinct subsystems in RODOS (*real-time online decision support system*) architecture (http://www.rodos.fzk.de). Several other systems that evaluate strategies in nuclear emergencies are also provided, ranging from rule-based systems to those using multi-attribute value and utility theory.

29.3.20 Expert Choice

http://www.expertchoice.com. Expert Choice (EC) software employs AHP as its core methodology. EC products include Expert Choice Desktop, the web-based Comparion™ Suite for group decision-making, and Expert Choice Inside for application integration. EC desktop versions have been used for decision analysis for more than 20 years. In addition to hierarchies of alternatives, the desktop version also offers a rating template library of best practice ratings scales, portfolio scenarios to visualize different scenarios on the efficient frontier, 3D plotting to see results in more meaningful ways, and support for Microsoft project integration and Oracle database interfaces. Comparion™ is a collaborative application for DMs supporting five decision processes: (1) defining goals, (2) structuring decisions, (3) assigning roles, (4) collaborating, and (5) choosing among options. A 10-day free trial version of Comparion™ is available.

29.3.21 FGM

http://www.ccas.ru/mmes/mmeda/soft/first.htm. FGM is MCDM software for visualizing the Pareto frontier in decision problems with multiple objectives. FGM employs the ***F****easible* ***G****oals* ***M****ethod* to explore all possible results of all feasible decisions [42] and the *Interactive Decision Maps* technique to display various decision maps. It supports both linear optimization algorithms (mostly based on approximation of multi-dimensional convex bodies by polytopes) and non-linear optimization algorithms (based on stochastic covering of bodies by systems of simple figures). FGM 3.1 supports a maximum of 100 decision variables, 5 decision criteria, and 300 non-zero elements in a decision model. FGM-based applications can be coded in C language for PCs in the Windows environment and workstations in the Unix environment. Demo software is available for download, as well as a

Java-based web-application of the FGM demo. The same research group responsible for FGM also provides *reasonable-goal-method-based* (RGM-based) MCDA software, discussed in Sects. 29.3.53 and 29.3.65.

29.3.22 FuzzME

http://fuzzme.wz.cz. FuzzME (**Fuzz**y Models of **M**ultiple-Criteria **E**valuation) is a tool for creating fuzzy models of multiple-criteria evaluation and decision-making. It was developed at the Faculty of Science at Palacký University Olomouc. Both quantitative and qualitative criteria are supported. For the aggregation of partial evaluations, different methods can be used, such as fuzzy weighted average, fuzzy ordered weighted average, or fuzzy Choquet integral [72]. FuzzME runs on Windows but requires the .NET framework. A demo version is available for download.

29.3.23 GeNIe & SMILE

http://genie.sis.pitt.edu. GeNIe & Smile is a decision-theoretic modeling system developed by the *Decision Systems Laboratory* at the University of Pittsburgh. The system provides a general-purpose modeling environment, SMILE (*Structural Modeling, Inference, and Learning Engine*), which is a fully portable library of C++ classes that implements decision-theoretic methods [22]. SMILE.NET is available with .NET framework, which can be used to create web-based applications. In addition, GeNIe, a Windows-based graphic click-and-drop interface for SMILE, is available to develop decision-theoretic models. The GeNIe & Smile system includes MADM-related modeling languages, such as multiple decision nodes, multiple utility nodes, and multiple attribute utility nodes. GeNIe, SMILE, and its wrappers, are available free of charge for any use.

29.3.24 GUIMOO

http://guimoo.gforge.inria.fr. GUIMOO (***G**raphical **U**ser **I**nterface for **M**ulti **O**bjective **O**ptimization*) is free software for analyzing results in MOO problems. It provides visualization of approximative Pareto frontiers and metrics for quantitative and qualitative performance evaluation, including S-metric, R-metric, size of the dominated space, coverage of the two sets and converge differences, etc. The latest release, GUIMOO-0.4-3 is developed in C++ in a Win32 desktop-based environment.

29.3.25 HIPRE 3+

http://www.sal.tkk.fi/en/resources/downloadables/hipre3. HIPRE 3+ is a software family that includes HIPRE 3+ (for desktop use), HIPRE 3+ Group Link (for group decision support), and Web-HIPRE. HIPRE 3+ is decision support software integrating AHP (*Analytic Hierarchy Process*) and SMART (*Simple Multiattribute Rating Technique*), which can be run separately or be combined in one. HIPRE 3+ provides a visual and customizable graphical interface for structuring, prioritization, and analysis of complex decision problems. HIPRE 3+ demo is restricted to run models with a maximum of three levels with three elements at each level. The full version of HIPRE 3+ can support up to 50 elements with up to 20 levels. HIPRE 3+ Group Link is group decision support software that combines individual prioritizations (through AHP) into an interval AHP model called preferences programming model [64]. HIPRE 3+ Group Link allows group members to combine AHP models, after individual AHP prioritizations are captured with HIPRE 3+. Web-HIPRE is a web-version of the HIPRE 3+ (http://www.hipre.hut.fi). It is a java-applet and provides a global platform for individual and group decision support.

29.3.26 HiPriority

http://www.quartzstar.com. HiPriority is designed to find best portfolio solutions, i.e. best subsets of alternatives subject to resource constraints. Weights are assigned to criteria and alternatives, and the software allows specifying dependencies between alternatives, as well as specifying mutually exclusive alternatives. HiPriority provides modeling of the consequences of interactions between options, such as multiple buffers to see the effects of forcing options in or out of a solution portfolio. To visualize benefit/cost ratios, the package creates simple value trees of cost elements together with their corresponding benefits, where cost is defined as any scarce resource. Miniature graphical views of the models are used as navigational tools. HiPriority is desktop-based and currently free to download as charity-ware.

29.3.27 HIVIEW3

http://www.catalyze.co.uk/?id=230. HIVIEW3 is a PC-based multiple criteria decision modeling tool original developed by Catalyze Ltd in association with LSE Enterprise (London School of Economics and Political Science). Hiview3 facilitates the building of decision models through choosing between mutually exclusive options. A complex decision modeling process is broken down into five simple

management stages. In stage 1, the outline of a model is constructed as a value tree structure and the options are defined; in stage 2, each of the action options is scored against the criteria set up in the outlined model; in stage 3, DMs set preferences on the relative importance of different aspects of the model; in stage 4, the model is analyzed; and lastly, recommendations are presented in stage 5. One unique feature of HIVIEW3 is its support for both quantitative and qualitative criteria, and weight assessments. The support for qualitative criteria is implemented through the inclusion of MACBETH methodology, and is designed to work equally in a workshop or back office environment. In addition, HIVIEW3 also supports group decision-making through Catalyze decision conferencing services. A 20 days free trial version is available for download. Educational licensing is also available, but support needs to be purchased separately.

29.3.28 IDS Multicriteria Assessor (IDS Version 2.1)

http://www.e-ids.co.uk. IDS Multicriteria Assessor supports multi-attribute decision analysis based on the *Evidence Reasoning* (ER) approach, a decision method for dealing with uncertainties in multi-attribute decision analysis (MADA) problems of both quantitative and qualitative natures [76]. Based on *utility theory* and *Dempster-Shafer theory of evidence* [18, 69], the ER approach uses a belief decision matrix (a generalized decision matrix with attributes assessed using a belief structure) [77] to systematically model MADA decision problems under different types of uncertainties, such as objectivity, randomness, and incompleteness. A free demo version that supports ten attributes is available for download, as well as various price options for academic, professional and enterprise versions.

29.3.29 IND-NIMBUS

http://ind-nimbus.it.jyu.fi. IND-NIMBUS is an interactive multi-objective optimization system for solving continuous, nonlinear problems with conflicting objectives subject to equality and inequality constraints. It employs the NIMBUS [45] (***N****ondifferentiable* ***I****nteractive* ***M****ultiobjective* ***Bu****ndle-based Optimization* ***S****ystem*) method based on a classification of the objective functions. In NIMBUS, the user is asked to express preferences by classifying the objective functions at the current Pareto optimal solution into up to five classes according to how the current solution should be improved. The classes are *functions to be improved*, *to be improved till some aspiration level*, *satisfactory at the moment*, *allowed to impair till some bound*, and *allowed to change freely*. New Pareto optimal solutions are then generated by solving single-objective sub-problems created based on the preference information. Connections for using some commercial solvers have also been developed. While there is no theoretic restriction on problem size, IND-NIMBUS in practice can

handle problems with less than ten objectives. IND-NIMBUS is desktop-based and can be connected with different simulator or modeling tools, such as Matlab. IND-NIMBUS can be used on the Windows and Linux platforms. It is commercial but free for academic testing purposes. Based on the same NIMBUS method, WWW-NIMBUS (http://nimbus.it.jyu.fi) is a free web-based version for academic teaching and research purposes.

29.3.30 INPRE and ComPAIRS

http://www.sal.tkk.fi/en/resources/downloadables/inpre. These two decision support tools are early implementations of techniques based on the imprecise preference statements in hierarchical weighting [63]. INPRE analyzes interval preference statements in the Analytic Hierarchy Process (AHP), while ComPAIRS works with similar statements in value tree analysis. The underlying methodology is similar to the one described in HIPRE 3+ (Sect. 29.3.25).

29.3.31 IRIS

http://www.uc.pt/feuc/ldias/software/iris. IRIS (*Interactive Robustness analysis and parameters' Inference for multicriteria Sorting problems*) is a DSS for sorting a set of actions (alternatives, projects, candidates) into predefined ordered categories, according to their evaluations (performances) on multiple criteria [21]. Application examples would be sorting funding requests according to merit categories, such as *very good*, *good*, *fair*, or *not eligible*, or sorting loan applicants into categories such as *accept*, *require more collateral*, or *reject*. IRIS uses a pessimistic concordance-only variant of the ELECTRE TRI method [19]. Rather than demanding precise values for the ELECTRE TRI parameters, IRIS allows one to enter constraints on these values. It adds a module to identify the source of inconsistency among the constraints when it is not possible to satisfy all of them at the same time, according to a method described by Mousseau et al. [47]. On the other hand, if the constraints are compatible with multiple assignments for the actions, IRIS allows drawing robust conclusions by indicating the range of assignments (for each action) that do not contradict any constraint. The software supports up to thousands of alternatives and up to 12 decision criteria. IRIS is windows-based and a demo version with limited problem sizes is available for download. IRIS is no longer actively supported, and an open source free alternative to IRIS is available as a plug-in for Decision Desktop (d2) software (see Sect. 29.3.11).

29.3.32 iMOLPe

http://www.uc.pt/en/org/inescc/products/molp_setup_limited. iMOLPe (Interactive Multi-Objective Linear Programming explorer) is an interactive software package to deal with linear programming problems with multiple objective functions, which includes scalarizing processes for computing efficient solutions based on weighted-sums, reference points and constraints on objective function values; distinct solution search strategies and visualization of results obtained with the TRIMAP method; and STEM, ICW and Pareto Race interactive methods. The downloadable version is limited to 6 objective functions, 100 decision variables and 100 functional constraints.

29.3.33 interalg

http://openopt.org/interalg. interalg (**inter**val **alg**orithm) is a free solver for multi-objective optimization with specifiable accuracy, possibly with categorical variables and general logical constraints. It uses an interval analysis based method and runs on Windows, Linux, or Mac. The software was initially released in March 2011, written in Python and NumPy. interalg includes a wide range of MOO functionalities, including searching for minima or maxima of non-linear problems, searching for global extrema of nonlinear problems with some discrete variables, searching full cover of Pareto front, and solution of non-linear equations. The software can handle some problems with hundreds of variables, though for some problems it may take too long to get a solution with the required accuracy.

29.3.34 iSight

http://www.3ds.com/products/simulia/portfolio/isight-simulia-execution-engine/isight-see-portfolio. Originally developed by Engineous Software, iSight is software for process integration and design optimization. It provides users with a suite of tools for creating simulation process flows to automatically exploit design alternatives and identify optimal performance parameters, taking advantage of its state-of-art multi-objective genetic algorithm approaches. In 2007, Engineous Software was acquired and iSight became a part of the Dassault Systèmes' SIMULIA brand product suite.

29.3.35 JAMM

http://idss.cs.put.poznan.pl/site/jamm.html. JAMM is designed to solve multi-criteria classification problems. Like 4eMka2 described in Sect. 29.3.2, JAMM is a family of software developed by the *Laboratory of Intelligent Decision Support Systems* (IDSS) at Poznań University of Technology to solve MCDM problems based on rough sets approach. The MCDM classification problem concerns the assignment of objects (alternatives) evaluated by a set of criteria to one of pre-defined and non-ordered decision classes, which is different from the sort problem in 4eMka2 where the decision classes are preference-ordered. The features in JAMM include: computation of rough approximations, induction of decision rules using DomLem and DomApriori (a complete set of rules), reduction of data table, classification of new examples, and data validation. It is Windows-based and available for free download. Based on communications with the software developers, JAMM is being replaced by jRank, a Java command-line application.

29.3.36 Logical Decisions

http://www.logicaldecisions.com. Logical Decisions for Windows (LDW) is decision support software for structuring and analyzing MADM problems. Based on MAUT, LDW offers five methods for assessing weights in value judgments, ranging from the *smarter* method, through *tradeoff* method, to AHP. The user interface is considered a significant attraction, with a graphical, point and click way to adjust weights. The results can be displayed in various ways, and one can compare pairs of alternatives to see their major differences. Interactive graphical sensitivity analysis displays are available. Logical Decisions offer a windows-based single user version (LDW for Windows), a group version (LDW for groups), and a portfolio version (LDW Portfolio). A 30 days free trial version of LDW is available and a free student version is also available with the book *Value-Added Decision Making for Managers* [11].

29.3.37 MakeItRational

http://makeitrational.com. MakeItRational organizes the process of multi-criteria evaluation by breaking it up into multiple judgments. MakeItRational is based on AHP and supports pair-wise comparisons of criteria. Evaluation results are represented in four types of charts: alternatives ranking, alternatives comparison, criteria weights, and sensitivity analysis. Desktop versions of MakeItRational are offered for Windows and Mac, as is an on-line version. A free demo version, which doesn't allow saving data, is available.

29.3.38 Markex (Market Expert)

http://www.ergasya.tuc.gr/software.html. Markex [44] is a multi-criteria decision support system for analyzing consumer behavior and market shares. The system uses consumer-based methodology [70] to support various stages in the product development process. The database of consumer survey results is analyzed to build different models for forecasting, data analysis, multi-criteria analysis, and branch choice. Specifically, Markex applies UTASTAR, an improved algorithm based on original UTA method, to model the multi-criteria consumer preferences. In addition, Markex employs three partial expert systems to support financial evaluation of the involved enterprises, selection of brand choice models, and selection of data analysis models. The software system is Windows-based, though the speed of the computer is critical in the solution of linear programs, calculation of utilities in the UTASTAR model, and representation of different models.

29.3.39 MindDecider

http://www.minddecider.com. MindDecider uses the concepts of mind mapping, MCDA, and AHP. A simple graphic interface allows fast click menu options to access decision constructs and then drag-and-drop onto a project canvas. User preferences can be modeled through utility functions and pair-wise comparisons. Uncertainty can be incorporated using fuzzy calculations feature. MindDecider is Windows-based and offers a personal version and a team version. Currently, the commercial version of MindDecider works only on the Microsoft.NET 2.0 framework. Mono versions for MaxOS and Android exist as beta versions. Users need 512MB free RAM space and up to 64MB free hard disk space to run MindDecider. Demo versions are available.

29.3.40 MINORA

http://www.ergasya.tuc.gr/software.html. MINORA (Multicriteria Interactive Ordinal Regression) [71] is an interactive decision support system based on the UTA method [34]. The interaction takes the form of an analysis of inconsistencies between the decision maker's rankings and those derived from utility measures. The method stops when an acceptable compromise is determined. The result is an additive utility function, which is used to rank the set of alternatives.

29.3.41 M-MACBETH and WISED

http://www.m-macbeth.com/en/m-home.html. M-MACBETH software deploys the MACBETH (*Measuring Attractiveness by a Categorical Based Evaluation Technique*) method, which is an interactive approach that requires only qualitative judgments about differences of values to help DMs quantify the relative attractiveness of options [2]. The user's qualitative preference judgment is captured through an interactive questioning procedure that compares two elements at a time. Judgmental disagreement or hesitation is also allowed. Using mathematical programming, the consistency of judgment is automatically verified and a numerical scale is generated based on seven semantic categories: *no*, *very weak*, *weak*, *moderate*, *strong*, *very strong*, and *extreme* difference of attractiveness. Weighting scales for decision criteria are generated in a similar manner, and an overall score for each option is calculated by weighted sum. The software provides some powerful tools like sensitivity analysis, structuring criteria in a value tree, robustness analyses of the final ranking, and profile comparison. M-MACBETH is desktop-based, with a minimum of 800×600px screen resolution running on a PC with Windows 2000 or earlier. A free demo version with a feature restriction of five criteria/options is available for download. Licensing options range from academic, to professional, and corporate versions with different pricing. An online tool called WISED is available as a new implementation of the MACBETH methodology with added online collaboration (both for evaluators and for the suppliers/representatives of the options under evaluation). It has a user-friendly layout, which makes it easier to undertake the tasks of scoring and weighting. WISED is available online as software as a service (SaaS) or installed on a companies' server.

29.3.42 modeFrontier

http://www.esteco.com/home/mode_frontier/mode_frontier.html. The name modeFrontier is in reference to the *Pareto frontier*, providing a boundary for "best" solutions. modeFrontier is multi-objective optimization software that allows easy coupling to any computer aided engineering (CAE) tool. The algorithms used in modeFrontier include linear and non-linear multi-objective optimization, Hurwicz algorithm [33], and Savage method [66]. The software also includes a MORDO (*Multiobjective Robust Design Optimization*) module [60] to support robust design analysis to check system sensitivity to any variation of the input parameters. MADA methods, including Hurwica, Savage, and soon with AHP, are also supported. According to the developers, the software supports hundreds of design alternatives and dozens of decision criteria. modeFrontier supports both Windows and Linux environments.

29.3.43 MOIRA and MOIRA Plus

MOIRA (***MO****del-Based Computerized System for Management Support to* ***I****dentify Optimal Remedial Strategies for* ***R****estoring Radionuclide Contaminated* ***A****quatic Ecosystems and Drainage Areas*) is a project financed by the European Commission. Both MOIRA DSS [56] and MOIRA-PLUS [46] are designed to help DMs to select countermeasure strategies for different kinds of aquatic ecosystems and contamination scenarios. Both systems include an evaluation module based on an additive multi-attribute value model to assess different alternatives. The utility assessment methods, probability equivalent method (PE) and certainty equivalent method (CE) [26], are implemented jointly to assess component value functions. The evaluation module also provides multi-parametric sensitivity analyses with respect to both weights and value. MOIRA-PLUS includes some functionality improvements based on the testing and assessment of MOIRA in various project. The improvements include prediction for the migration of heavy metals and improved software interfaces. Both versions are windows-based.

29.3.44 NAIADE

http://www.aiaccproject.org/meetings/Trieste_02/trieste_cd/Software/Software.htm. NAIADE (***N****ovel* ***A****pproach to* ***I****mprecise* ***A****ssessment and* ***D****ecision* ***E****nvironments*) is a discrete multi-criteria method [49] which provides an impact or evaluation matrix that may include either crisp, stochastic, or fuzzy measurements of the performance of an alternative with respect to an evaluation criterion. A peculiarity of NAIADE is the use of conflict analysis procedures integrated with the multi-criteria results. NAIADE can give rankings of the alternatives with respect to the evaluation criteria (leading to a technical compromise solution), indications of the distance of the positions of the various interest groups (possibly leading to convergence of interests or to coalition formation), and rankings of the alternatives with respect to the actors' impacts or preferences (leading to a social compromise solution). NAIADE runs on Windows-based systems.

29.3.45 OnBalance

http://www.quartzstar.com. OnBalance is based on a simple weighting approach: each decision option is scored against each decision criterion, and each decision criterion is given a weight. It then computes an overall weight for each option. Multiple hierarchies, called trees, using different weights, can be created to allow for different perspectives. Thus the approach appears to be similar to AHP, but no information is given as to how the overall weights are calculated. The package

is designed to be easy to use by anyone, without much technical understanding. The interface of OnBalance is specifically designed for group decision-making and weight sets feature can be created to capture multiple stakeholders' different opinions. The current version OnBalance3 is free to download as charity-ware. OnBalance is desktop-based.

29.3.46 Optimus

http://www.sigmetrix.com/optimus.htm. Optimus is process integration and design optimization software, bundling a collection of design exploration and optimization methods. A single main window graphical user interface provides all the functionality. The numerical simulation methods of Optimus are based on gradient-based local algorithms or genetic global algorithms, both for single or multiple objectives with continuous and/or discrete design variables. Optimus includes mechanical variation effects in multi-objective performance optimization, multi-physics simulation and optimization, design robustness optimization, and manufacturing cost optimization. Optimus is desktop-based and a demo is available by request.

29.3.47 ParadisEO-MOEO

http://paradiseo.gforge.inria.fr. ParadisEO is a software framework for metaheuristics, and the MOEO (*metaheuristics for multiobjective optimization*) module implements evolutionary multi-objective optimization techniques [10, 37]. It is white-box, object-oriented, C++, portable across both Unix-like and Windows systems. ParadisEO is based on Evolving Objects (EO), a template-based ANSI-C++ compliant evolutionary computation library. There is conceptually no restriction on problem size, however, classical Pareto-based metaheuristics usually solve problems with up to five objectives. As an open source framework, ParadisEO is compatible with Windows, Unix-like, and MacOS environments. It also supports parallel and distributed architectures. The related source code is maintained and regularly updated by the developers.

29.3.48 Pareto Front Viewer

http://www.ccas.ru/mmes/mmeda/soft/third.htm. Pareto Front Viewer (PFV) [40] is software for interactive Pareto frontier visualization for nonlinear models in the case of two to eight criteria. PFV can be combined with any Pareto frontier approximation technique. PFV is windows-based and a demo version (PFV 1.2), as well as the Manual, is downloadable. The demo version is restricted to 5 criteria and 1000 criteria points.

29.3.49 Prime Decisions

http://www.sal.tkk.fi/en/resources/downloadables/prime. PRIME Decisions [62] emphasizes its ability to use incomplete preference information. It relies on the PRIME method that uses interval valued ratio statements of preference. These lead to linear constraints for a series of linear programming problems. Solving the linear programs leads to dominance structures. There is an "elicitation tour" to guide the decision maker. Because of the large number of linear programs that must be solved, the approach is best suited to problems with relatively few non-dominated alternatives. The software runs on Windows platform and is downloadable for academic use.

29.3.50 Priority Mapper

http://www.infoharvest.com/ihroot/gis/index.asp. Priority Mapper is an extension of ESRI's ArcMap, which integrates priority analysis with *geographical information systems* (GIS). It is targeted at managers and executives to realistically prioritize actions related to geographically distributed assets and resources. The output is in the form of visual representations of the prioritizations and recommended alternatives. The target operating platform is Windows. Due to a bug in Microsoft's installer for SQL, the beta launch of Priority Mapper was delayed.

29.3.51 Prism's Group Decision Support System

http://www.prismdecision.com/solutions/decision-support. Prism's Group Decision Support System provides group multi-criteria decision support. The software is based on a simple weighted criteria scoring approach for MCDA problems. After developing a set of possible solutions and agreeing to a set of decision criteria, the group members weigh each criterion using a pair-wise comparison analysis. The criteria weights, solution set, and criteria set consist of a multiple criteria decision matrix. The group members assess each solution against each criterion and vote on a 1 to 9 scale. In case of disagreement, a revote is taken after group discussion. After all cells are voted, the raw worth (sum of the 1 to 9 votes) and the weighted worth for each solution are displayed.

29.3.52 PROBE

PROBE (Portfolio Robustness Evaluation) is a decision support system developed to aid a decision-maker in the task of selecting a robust portfolio of projects in the presence of limited resources, multiple criteria, different project interactions, and several types of uncertainty [43]. PROBE identifies all efficient portfolios, either convex or non-convex, depicts them in a cost versus benefit graph within a given portfolio cost range, and allows performing in-depth interactive analysis of the robustness of selecting a proposed portfolio. PROBE integrates two main architectural components: a multi-criteria decision analysis component and a portfolio decision analysis component. The multi-criteria component allows the user to structure the benefit criteria in the form of a value tree, input data for the costs of the projects and their benefit scores on each bottom-level criterion of the value tree, and weights for the criteria at each level of the value tree. A hierarchical value model is used for aggregation evaluation. The portfolio component uses optimization to find all the efficient portfolios for the given project costs and aggregated benefit value scores for a user-defined portfolio cost range. The modeling of uncertainty is also supported.

29.3.53 RGDB

http://www.ccas.ru/mmes/mmeda/rgdb/index.htm. RGDB (*Reasonable Goal for Database*) is a prototype version of a Web application server that can support easy selection of large databases for preferred items, such as preferable goods and services, suspicious data, efficient investment strategies, etc. It is a Web implementation of the RGM/IDM (*Reasonable Goals Method/Interactive Decision Maps*) technique [41] using Java applets. From the same research group as FGM (see Sect. 29.3.21), RGM uses IDM to support the identification of goals. However, the identified goals might not be feasible, and thus a reasonable goal is identified and feasible decisions (based on users' preferences) that are in line with the goal are selected. When applying RGM for databases, users can select preferable rows from thousands or even millions of rows by simply clicking a preferable criterion point (a preferable goal) on a picture and then receiving one or more rows that are in line with the identified goal. The prototype RGDB server supports up to 5 attributes and up to 2000 alternatives. Five different versions of the applet are available: (1) the simplest applet for beginners, (2) the applet for negotiation support, (3) the applet with an additional matrix of decision maps, (4) the applet for negotiation support with matrix of decision maps, and (5) the applet with a structured procedure of Pareto frontier exploration. Internet Explorer and Java 1.3 are needed to use the RGDB application server.

29.3.54 RICH Decisions

http://www.rich.tkk.fi/index.html. RICH Decisions is a web-based free decision support software based on the RICH (*Rank Inclusion in Criteria Hierarchies*) method [65] which admits incomplete ordinal preference information in hierarchical weighting models. It allows the DM to state such preference information by specifying pairs of two sets, possibly of different size, of which the first consists of attributes and the second of importance rankings that are attained by the attributes in the first set (e.g., a set of three attributes of which one has the highest importance ranking, or a singleton set consisting of one attribute which is the second or third most important). Taken together, these pairs define the set of feasible attribute weights. RICH Decisions has a graphical user interface for structuring alternatives and attributes in both flat and multi-level value trees. Scores can be elicited by assessing all alternatives with regard to a given attribute or by assessing a given alternative across all attributes. Based on the elicited score and weight information, RICH Decisions derives decision recommendations by checking dominance relations and by applying decision rules. Results such as value intervals and dominance relations are shown graphically. The software supports up to 29 alternatives. The computations can be time-consuming if there are more than ten attributes. RICH Decisions is a Java-applet, which requires a Java-enabled browser. For security reasons, only models can be saved on the server.

29.3.55 Rubis (Plug-in)

http://www.decision-deck.org/d2/plugins.html. Developed as a plug-in for Decision Desktop Software/d2 (see Sect. 29.3.11), Rubis, a bipolar-valued concordance based decision aiding method [4], is a progressive decision aiding tool to help a DM determine a single best decision alternative. The methodology focuses on pair-wise comparison of alternatives, which lead to the bipolar-value outranking digraph.

29.3.56 SANNA 2009

http://nb.vse.cz/~jablon/sanna.htm. SANNA 2009 is a Excel add-in for multi-criteria decision support. It is freeware that contains a support tool for estimation of weights using several methods including pair-wise comparisons and incorporates basic MCDA methods including WSA, TOPSIS, ELECTRE I and III, PROMETHEE I and II, ORESTE, and MAPPAC. It can solve problems up to 180 alternatives and 50 criteria.

29.3.57 MC-SDSS for ArcGIS

http://arcscripts.esri.com/details.asp?dbid=16980. MC-SDSS (*multiple criteria spatial decision support system*) is a .NET extension of ArcGIS desktop to solve optimization tasks (based on spatial data) using SAW (*simple additive weighting*) and TOPSIS (*technique for order preference by similarity to ideal solution*) scoring methods.

29.3.58 SOLVEX

http://www.ccas.ru/pma/product.htm. SOLVEX is a Fortran library of more than 20 numerical algorithms for solving unconstrained, nonlinear constrained, global minimization, and multi-criteria optimization problems [55]. The MOO algorithms cover additive convolution, Chebyshev convolution, goal programming, and epsilon approximation. Two versions, SOLVEX Windows and SOLVEX DOC are available for download.

29.3.59 TransparentChoice

http://www.transparentchoice.com. TransparentChoice is a Web-based application for collaborative decision-making, based on AHP. The software is built for providing the following "must-have" features for AHP: intuitive way to build and visualize hierarchy; option to reduce the number of pairwise comparisons; consistency checking of pairwise comparison results and resolving inconsistencies; collaborative decision making and voting; and sensitivity analysis. In TransparentChoice, each decision starts by creating a project for a specific decision goal, followed by defining alternatives, criteria, and custom scales. The collaboration is supported through the User Tab, allowing multiple users' decision inputs. Once all decision inputs (alternatives, criteria, and scales) are captured, each user is can evaluate each alternative using pairwise comparison, and collective votes are organized by reviewing input with assigned voting strengths to individuals and groups. The results for final decision are presented in graphic format, including criteria priorities and alternatives ranking. A free 30-day trial version is available.

29.3.60 Triptych

http://www.stat-design.com/Software/Triptych.html. Triptych is an Excel-based tool suite that asserts to capture the voice of customers and translate it to design

requirements in product development. The software includes different worksheets implementing different MCDA methods, among which are AHP, Pugh, TOPSIS (*Technique for Order Preference by Similarity to Ideal Solution*), and the SDI Method. The AHP worksheet can support an AHP matrix with up to 200×200 item and includes a Consistency evaluation. The TOPSIS worksheet can support a TOPSIS matrix with up to 200 criteria and 200 options. The Pugh, TOPSIS, and SDI Method worksheets can support a matrix with up to 200 criteria and 200 options. Both qualitative and quantitative options are supported in the TOPSIS worksheet. A 10-day free trial is available.

29.3.61 TRIMAP

http://www.inescc.pt/ingles/produtos.php. TRIMAP [14] is an interactive approach that explores the Pareto optimal set for three-criterion linear programming models. The aim is to aid the decision maker in eliminating parts of the Pareto optimal solution set that are judged to be of less value. The limitation to three objectives permits graphical displays that facilitate the decision maker's information processing. The procedure does not converge to a particular solution, but the decision maker can stop the process when sufficient information has been learned about the Pareto optimal solutions. A demo is available.

29.3.62 UTA Plus

http://www.lamsade.dauphine.fr/spip.php?rubrique69. UTA Plus is the latest Windows implementation of the UTA method, originally proposed in 1982 [34]. The method can be used to solve multi-criteria choice and ranking problems on a finite set of alternatives. It constructs an additive utility function from a weak preference order defined by the user on a subset of reference alternatives. Constructing the utility function, based on a principle of ordinal regression, requires solving a small LP-problem. The software proposes marginal utility functions in piece-wise linear form based on the given weak order, and then allows the user to interactively modify the marginal utility functions, helped by a graphical user interface. Software and user manual are available for download.

29.3.63 Very Good Choice

http://www.verygoodchoice-addin.com. Very Good Choice (VGC) is an excel add-in for supporting both multi-alternative ranking and sorting problems. Based on the ELECTRE family of outranking methods, VGC allows users to determine

alternatives and qualitative criteria and weights, and then score the alternatives. Ranked alternatives, including non-distinguishable alternatives (alternatives with the same rank), are presented in an ordered table. All the data about the decision process can be stored in an XML format. A free version is available for download.

29.3.64 VIP Analysis

http://www.uc.pt/en/feuc/ldias/software/vipa. VIP (*Variable Interdependent Parameters*) Analysis [20] was proposed to support the selection of the most preferred alternative from a list, considering the impacts of each alternative on multiple evaluation criteria. While the approach uses a basic additive aggregation value function, it permits the decision maker to provide imprecise parameters for the criteria importance (scaling weights). In the authors' words, they propose "a methodology of analysis based on the progressive reduction of the number of alternatives, introducing a concept of tolerance that lets the decision makers use some of the approaches in a more flexible manner." Several output options exist depending on the size of the problem and the nature of the input data (including value range, maximum regret for each alternative, and dominance relations). The software supports a thousand alternatives and up to 49 criteria. The Windows-based software is distributed for free upon request. A tutorial is available for download.

29.3.65 Visual Market/2

http://www.ccas.ru/mmes/mmeda/soft/second.htm. Visual Market/2 is a Windows-based implementation of the RGM/IDM technique for visualization of large databases (including GIS), similar to RGDB (Sect. 29.3.52). In addition to returning a small number of items that correspond to the identified goal, auxiliary data filtering and pseudo-decision trees are also provided. The software supports a maximum of 12,000 alternatives and up to 7 decision criteria. It was developed for Windows XP; a new version for Windows 7 and Windows 8 is under development. A demo of Visual Market/2 version 2.1 and a manual are available for download.

29.3.66 VISA

http://www.visadecisions.com. VISA (*Visual Interactive Sensitivity Analysis*) is based on an approach described Belton and Stewart [3]. Applying a linear, multi-attribute value function, it has been available in a Windows version since 1994, emphasizing a friendly graphical interface for adjusting the criteria hierarchy and other components of the model. For example, an interactive value tree can be

structured to show all criteria on the main decision. Users can interactively provide input of weights and scores using bar charts, thermometer scales, or numerical input. The weights and scores can be adjusted by dragging the computer mouse, and the effects can be seen immediately on several output windows. VISA version 8 is available as *Standard* (a stand-alone desktop application), *Education* (Windows stand-alone campus license and free 3 month student licenses), and *Multi-user*. A 30-day free trial is also available.

29.3.67 VisualUTA

http://idss.cs.put.poznan.pl/site/visualuta.html. VisualUTA is developed by LDSS (*Laboratory of Intelligent Decision Support Systems*) at Poznan University of Technology, Poland, the same developer as for 4wMka2 (Sect. 29.3.2) and JAMM (Sect. 29.3.35). It is the first implementation of the UTA-GMS method [31] for multiple criteria ranking of alternatives. The method is interactive, with progressive pair-wise comparisons. The software is free for downloading.

29.3.68 WINGDSS

http://www.oplab.sztaki.hu/wingdss_en.htm. WINGDSS [15] is a group decision support system for multiple attribute problems. WINGDSS provides a final score for every alternative and thus a complete ranking. Voting powers are assigned to each decision maker for each criterion. Both subjective and factual criteria can be used. Sensitivity analysis permits studying the effect of the variations of parameters such as individual preferences, voting powers, and scores. It includes an attribute tree editor, data from the editor, and dynamic linkage to external databases. WINGDSS is Windows-based.

29.3.69 WINPRE

http://www.sal.tkk.fi/en/resources/downloadables/winpre. WINPRE [64] is a MCDA tool available from the *Systems Analysis Laboratory* in Finland, the group that also offers PRIME Decisions (Sect. 29.3.49) and HIPRE 3+ family (Sect. 29.3.25). WINPRE relies on a method called PAIRS (*Preference Assessment by Imprecise Ratio Statements*) that permits the decision maker to state a range of numbers to indicate preferences among alternatives. These preference statements result in linear constraints that lead to a feasible region for each criterion that is consistent with the decision maker's judgments. The software is available free for academic use.

29.4 Concluding Remarks

Increases in computing power have been at the heart of the substantial growths in applications of MCDA [74]. In 2005, Weistroffer et al. provided a comprehensive survey of MCDA software, but many of the software packages presented in that survey have been discontinued or are no longer supported. More recently, Poles et al. [54] reviewed MOO software available since 1999, focusing on the tools and features that advisable MOO software should contain. An early empirical evaluation of five MCDA software packages and a comparison of their usefulness to a basic spreadsheet package was conducted by Zapatero et al. [78]. Taking a different angle, Seixedo and Tereso [68] constructed an AHP-based MCDA software application for selecting MCDA software and presented the MCDA tools using a similar approach to Weistroffer et al. [75]. Mustajoki and Marttunen [50] recently did a comparison of some MCDA software with a specific focus on applicability to environmental impact assessment.

An updated review of the current state of MCDA software provides insights of not only what has been improved or not changed in MCDA software application development, but also what will be interesting for the future. Several findings from the previous software review Weistroffer et al. [75] are still valid. First, a large majority of commercially marketed packages deal primarily with MADM problem models and use relatively simple algorithmic approaches. For example, many commercial software packages adopt MAUT and/or AHP methods, where AHP and SMART are frequently implemented together. Second, the large variety of sophisticated MCDM methods proposed in the literature have mostly been implemented only on an ad hoc basis to solve a specific problem situation, or as experimental software to demonstrate the salient features of the proposed method. There are still relatively few commercial MOO software packages, though many MOO methods have been proposed in the literature. The available MOO commercial packages are mostly either integrated solver engines (e.g. Analytica Optimizer), or integrated in application-specific software solutions (e.g. iSight, modeFrontier).

Changes in MCDA software are also evident. First, MCDA has begun to penetrate many new areas of research and applications. For example, MCDA methods have been applied in new engineering applications, such as ESY for nuclear emergencies and iSight in 3D simulation design. Another example is spatial planning and management, where MCDA software packages are designed for integration with GIS, such as MC-SDSS for ArcGIS, Priority Mapper, and Visual PROMETHEE PROMap, and engineering applications. Second, MCDA software solutions have moved towards web-based and service-oriented platforms, facilitated by increasing computing power and improved Internet technology. Third, it is interesting to see MCDA applications, such as ParadisEO-MOEO and Decision Lab 2000, that have adopted an open source philosophy, an approach that has already become a major part of general, mainstream information technology development. Open architecture provides greater opportunities for implementation of state-of-the-art MCDA methods and continuous software enhancements by open

source developers. It also allows the flexibility to adapt specific MCDA methods for particular business problems. However, the learning curves for open source solutions are quite steep and open source development may require sophisticated understanding of MCDA principles and methods. Nevertheless, we expect to see more open source initiatives in MCDA software development in the future. Another area for potentially more future MCDA software development is mobile MCDA applications. Currently, MCDA mobile applications seem to be designed only for personal decision-making. We did not include these in our survey, but some examples of such applications include Mobile Decision Maker by Broad Research Software (http://mobiledecisionmaker.com), decision buddy (http://www.decisionbuddyapp.com), and Decisionaker by lemonway (http://www.lemonway.com/index.php/products/14-ios-application/58-decisionaker-support-page).

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