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MULTIPLE CRITERIA DECISION MAKING (MCDM) METHODS IN ECONOMICS: AN OVERVIEW

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Abstract. The main research activities in economics during the last five years have significantly increased. The main research fields are operation research and sustainable development. The philosophy of decision making in economics is to assess and select the most preferable solution, implement it and to gain the biggest profit. Preferences are used in a lot of problem situations both in individual and organizational decision making processes. A number of effective decision making methods that support decisions under conditions of multiple criteria have appeared in the last decade. This paper presents a panorama of decision making methods in economics and summarizes the most important results and applications over the last five years. This paper considers decision making in light of the recent developments of multiple criteria decision making methods (because classical methods are overviewed in a lot of earlier publications). Authors of different approaches, pioneering studies and works are presented in short.

Keywords: economics, multiple criteria, decision making, MCDM, analysis, overview.

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JEL Classification: C02, C35, C53.

1. Introduction

Decision making problems are of crucial importance in economics. The main research activities in economics during the last five years have significantly increased. The main fields are operation research and sustainable development. Success in economics and business is a straightforward matter: focus on society, government, stakeholders, customers, and amaze them with experiences that exceed their expectations. Decision analysis is widely recognized as a sound prescriptive theory.

On the basis of intensive and productive scientific works and the high achievements, EURO Working Group OR in Sustainable Development and Civil Engineering (EWG-ORSDCE) was established in 2009 (http://www.orsdce.vgtu.lt/?id=54427.33863).

Publication in 1776 of *The Wealth of Nations* by Adam Smith has been described as the effective birth of economics as a separate discipline (Blaug 2007). Katona (1953) presented and contrasted the most common forms of methodologies of the economic principle of rationality in both psychology and economics, and a general discussion of the role of empirical research among psychologists in studies of economic behaviour was initiated.

Current economic models developed out of a broader field of political economy in the late 19th century, owing to a desire to use an empirical approach more akin to the physical sciences (Clark 1998). Rationality is a central principle in decision-making, where a rational agent is specifically defined as an agent who always chooses the action which maximises its expected performance (Johnson-Laird and Byrne 1991). Rational choice theory, also known as choice theory or rational action theory (Arrow 1989), is a framework for understanding and often formally modelling social and economic behaviour. The basic idea of rational choice theory is that patterns of behaviour in societies reflect the choices made by individuals as they act by comparing the costs and benefits of different courses of action. It is the main theoretical paradigm in the currently-dominant school of microeconomics.

The fact that people act rationally has been recognised by many scientists, but they have seen rational actions alongside other forms of action, seeing a human action as involving both rational and non-rational elements. Actions are often expressed as a set of actions. In rational choice theories, individuals are seen as motivated by the wants or goals that express their 'preferences'. Decision makers act within specific, given constraints and on the basis of the information that they have about the conditions under which they are acting. Durkheim in 1893 (Durkheim 1984) argued that all rational economic actions occur within an institutional framework of norms that cannot itself be explained as a result of rational action alone. Groups and organisations, business enterprises, and others may, then, all figure as collective actors whose individual intentions are aggregated and an agreed policy formulated (Hindess 1988). Individuals or organizations are called rational if they make optimal decisions in pursuit of their goals.

Von Winterfeldt's and Edwards works on multiple stakeholder decision analysis and behavioural decision theory generated a more formal approach to multiple attribute utility analysis (von Winterfeldt and Edwards 1986).

Perhaps the most important ideas are that a common value structure can be created even when stakeholders violently disagree about the issues at hand; that conflicts are often about specific value tradeoffs or facts; that conflicts about values can be expressed as different weights; and that conflicts about facts can be modelled by using judgments from different experts. Most importantly perhaps was the finding that decision analysis can be useful to help multiple stakeholders understand what they agree and disagree about, focus on the things that they disagree about and explore options that are better for everyone involved.

It is believed that a good rationale must be independent from personal emotions, feelings, instincts or culturally specific, moral codes and norms. If these minimum requirements are not satisfied, the analysis may be termed irrational. It is evident that no human has ever satisfied this criterion.

Weber (Max Weber (1864–1920) distinguished between four ideal-types of action (Weber 2011):

- Affectual, determined by an actor's specific affect, feeling, or emotion;
- Traditional action;
- Value-rational action. Here the action is undertaken for what one might call reasons intrinsic to the actor: some ethical, aesthetic, religious or other motive, independent of whether it will lead to success;
- Means-end rational action.

As expressed by Weintraub (2007), neoclassical economics rests on three assumptions:

- People have rational preferences among outcomes;
- Individuals maximize utility and firms maximize profits;
- People act independently on the basis of full and relevant information.

Bounded rationality is the idea that in decision-making rationality of individuals is limited according to the information they have, the cognitive limitations of their minds, and the finite amount of time they have to make decisions (Elster 1983). Another way to look at bounded rationality is that because decision-makers lack the ability and resources to arrive at the optimal solution; they instead apply their rationality only after having greatly simplified the choices available (Gigerenzer and Selten 2002).

Economists determine priorities of actors by strictly mathematical descriptions. They make a set of assumptions which are referred to as the assumptions of a human's rational behaviour.

Rational choice theory makes two assumptions about individuals' preferences for actions:

- Completeness: all actions can be ranked in order of preference (indifference between two or more is possible).
- Transitivity: if action a_1 is preferred to a_2, and action a_2 is preferred to a_3, then a_1 is preferred to a_3.

Together these assumptions form the result that given a set of exhaustive and exclusive actions to choose from, an individual can rank them in terms of his preferences, and that his preferences are consistent.

An individual's preferences can also take forms:

- Strict preference occurs when an individual prefers a_1 to a_2, but not a_2 to a_1.
- In some models, a weak preference occurs when an individual has a preference for at least a_j, similar to the mathematical operator $\leq$.
- Indifference occurs when an individual does not prefer a_1 to a_2, or a_2 to a_1.
- In more complex models, other assumptions are often incorporated, such as the assumption of independence axiom. Also, with dynamic models that include decision making over time, time inconsistency may affect an individual's preferences.

From the first days of the mankind on earth, there is evidence of countless human decision situations related to real life problems with many desirable attributes. These attributes are often referred to in literature as criteria or Performance Measures. All interested parties think about different touch points and allow them to rank feasible alternatives in importance, need for improvement, and overall criteria selection. The different touch points need to be reengineered to conduct the experience according to the criteria that the interested parties defined as important.

2. Operations research in economics

An Operations Research (OR) is the application of scientific method to the management of organized systems such as industrial production systems, government and social programs, and defence systems. OR (also referred to as decision science or management science) is the application of science to the solution of managerial and administrative problems; it focuses on the performance of organized systems taken as a whole rather than on their parts separately. Its techniques and methods, and the areas to which they are applied, can be expected to continue to expand rapidly (Industrial Engineering... 2011). OR is an interdisciplinary mathematical science that focuses on the determination of the maximum or minimum of some real-world objectives. The environment in which decisions must be made is more complex than ever before. Companies use operations research to devise ways and means to maximize their profits and restrict their losses and risks. Also, they devise means to produce at lower costs or produce more quantities at the same costs.

Many years of research effort have been devoted to developing various mathematical models which could describe decision maker behaviour. These models are applied in OR. Some of the tools used by operational researchers are statistics, optimization, probability theory, queuing theory, game theory, graph theory, decision analysis, mathematical modelling and simulation.

The main stages of conventional OR are as follows:

- Creating the model, which is proper to the problem solution;
- Selecting the optimality criterion;
- Choosing preferable solution.

The primary step in many economical studies and in OR is the construction of models representing the reality. Typical decision making problems imply the creation of a subjective model representing personal perception of a decision problem. Decision making has two roots: economical utility theory and OR.

With expanded technologies and impact on environment, as well as sustainable development of economy, the use of OR is widely extending. Informed stakeholders, society, government and scientists require solving problems taking into account multiple criteria. Such problem solution approach enables taking high quality decisions. A distinction between OR and Decision making methods is that the latter have several different methods to evaluate quality of decisions made. Compromise among several criteria could be determined by the person (group of persons) who makes decisions.

There is a separated class of models for decision making methods which are of objective character (similar to the OR), but quality of the made decision is determined according to a several criteria. This class of problems is named multiple criteria models with objective described models. This class is position between OR and decision-making.

Forecasting is one of the most significant parts in decision-making. The reason of this is that decisions must be made before acting and it deals with future. Executives make forecasts as an essential part of their work. International institute of Forecasters sponsored classifying and the main forecasting principles are presented (Fig. 1). The Methodology Tree for Forecasting classifies all possible types of forecasting methods into categories and shows how they inter-relate.

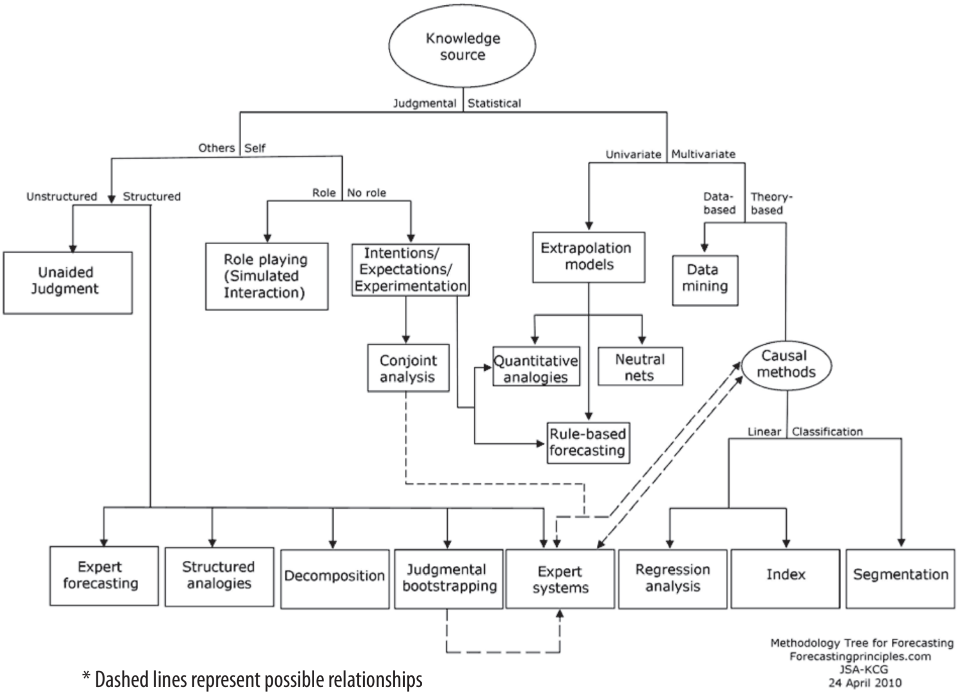


Fig. 1. The Methodology Tree for Forecasting (Forecasting Principles 2011)

Developing economics, changing environment, sustainability of decisions are the reasons for the rapid development of new OR techniques and many of those techniques were adopted for problem solution in economics. But in reality, the modelling of economical problems is based on a different kind of logics, taking into consideration the following elements (i.e. multiple criteria paradigm (Roy 1988)):

- The existence of multiple criteria;
- The conflicting situation between the criteria;
- The complex, subjective and ill-structured nature of the evaluation process;
- The introduction of financial decision makers in the evaluation process.

The main limitation of operations research is that it often ignores the human element in the production process. This science is technology driven and does not take into account the emotional factors and absenteeism of employees.

3. Multiple criteria decision making (MCDM) methods in economics

In the field of MCDM, there are two schools of thought that a human choice is based on: a French school and an American school (Lootsma *et al.* 1990). The French school mainly promotes the outranking concept for evaluating discrete alternatives (Roy 1968). The American school is based on multi-attribute value functions and multi-attribute utility theory (MAUT) (Keeny and Raiffa 1976).

Multiple criteria decision making, as described by Vincke (1992), is the most directly characterised by a set of multiple criteria method. From 1950s onwards, there had been a large number of refined MCDM methods developed and they differ from each other in the required quality and quantity of additional information, the methodology used, the user-friendliness, the sensitivity tools used, and the mathematical properties they verify. Vincke succinctly outlines a disaggregation of the overall of the multiple criteria decision into three components of multiple attribute utility theory, outranking methods and interactive methods.

Siskos and Spyridakos (1999) presented a survey of the history and the recent status of the multiple criteria decision support systems. Wang *et al.* (2009) in review of multi-criteria decision analysis aid in sustainable energy decision making pointed out that MCDM methods have become increasingly popular in decision-making for sustainability because of the multi-dimensionality of the sustainability goal and the complexity of socio-economic and biophysical systems.

Carlsson and Fullér (1996) stated that there are four quite distinct families of MCDM methods:

- The outranking;
- The value and utility theory based;
- The multiple objective programming;
- Group decision and negotiation theory based methods.

Fuzzy MCDM has basically been developed along the same lines, although with the help of fuzzy set theory a number of innovations have been made possible.

Utility theory is interested in people's preferences or values and with assumptions about a person's preferences and with judgements of preferability, worth, value, goodness or any of a number similar concept that enable them to be presented in numerically useful ways (Fishburn 1965, 1968). In decision theory, utility is a measure of the desirability of consequences of the courses of action that applies to decision making under the risk, i.e. under uncertainty within known probabilities.

The concept of utility applies to both single-attribute and multi-attribute consequences. The fundamental assumption in utility theory is that the decision maker always chooses the alternative for which the expected value of the utility is maximal. If that assumption is accepted, utility theory can be used to predict or prescribe the choice that the decision maker will make, or should make, among the available alternatives. For that purpose, a utility has to be assigned to each of the possible (and mutually exclusive) consequences of every alternative. A utility function is the rule by which this assignment is done and depends on the preferences of the individual decision maker. In utility theory, the utility measures of the consequences are assumed to reflect a decision maker's preferences in the following sense:

- The numerical order of utilities for consequences preserves the decision maker's preference order among the consequences;
- The numerical order of expected utilities of alternatives preserves the decision maker's preference order among these alternatives.

The art of applying multi-attribute utility has expanded since 1976. There should be significant interplay between descriptive studies of how people do process information and make decisions and prescriptive decision analysis to help people make decisions that are consistent with their values and understanding of the problem (Tsoukias and Vincke 2011).

Preferences are used in a lot of decision making problem situations in economics. The first attempt to give an account about preference relations can be referred to Von Neumann and Morgenstern (1944). Savage (1954) was the first to introduce the foundation of the subject. Most of the economical, industrial, financial or political decision problems are multiattribute. The problem to estimate utility function representing the actor's preferences in the multidimensional case (multiattribute utility theory) is very important. The problem of the selection or the ranking of alternatives submitted to a multicriteria evaluation is not an easy problem. Usually, there is no optimum solution; no alternative is the best one for each criterion. Better quality implies higher price. The criteria are conflicting. Compromise solutions have to be considered.

The subject was investigated in Keeney and Raiffa (1976), where the basic conditions under which their use is possible are introduced. Rough set theory is a tool for dealing with granularity, classification, vagueness and incompleteness in data analysis (Zhu 2009). In order to achieve this goal, researchers have proposed many methods other than classical logic, for example, fuzzy set theory, rough set theory, computing with words and granular computing, computational theory for linguistic dynamic systems.

It is obvious that uncertainty is a typical feature of preferences when it is necessary to define calculus so as to handle these situations operationally. Fuzzy set theory could then be a tool (Zadeh 1975a, b, c). The first fuzzy outranking relation is defined as theoretical background for the ELECTRE III method. Greco *et al.* (1999, 2000 and 2001); Pawlak *et al.* 1995) pointed at peculiarities of fuzzy sets and rough sets using in MCDM.

A linguistic variable is a variable whose values are expressed in linguistic terms (Zimmermann 1985). The concept of a linguistic variable is very useful in dealing with the situations which are too complex or not well-defined to be reasonably described in conventional quantitative expressions (Larichev and Moshkovich 1997; Larichev and Brown 2000; Ustinovichius *et al.* 2009, 2010, 2011). Fuzzy numbers are introduced to appropriately express linguistic variables. In the area of fuzzy reasoning, the two–tuple linguistic representation method (Herrera *et al.* 2000; Liu and Zhang 2011) is widely applied for computing with words.

Problem selection and alternative creation are critically important. Investigation and aggregation of values, which describe the reason actors are interested in decision situation, are referred to as value-focused thinking. The aim of this model is to create better alternatives and aggregation of individual preferences for any decision problem. Many of the complex problems faced by decision makers involve multiple conflicting objectives (Keeney 1982).

4. Classification of discrete multiple criteria methods

There are a lot of MCDM methods (Guitoni and Martel 1998). MCDM approaches are major parts of decision theory and analysis. Hwang and Yoon (1981) grouped the MCDM methods according to the available information. Real-world decision making problems are usually complex and no structures are to be considered through the examination of a single criterion, or point of view that will lead to the optimum decision. Operation in the marketplace requires

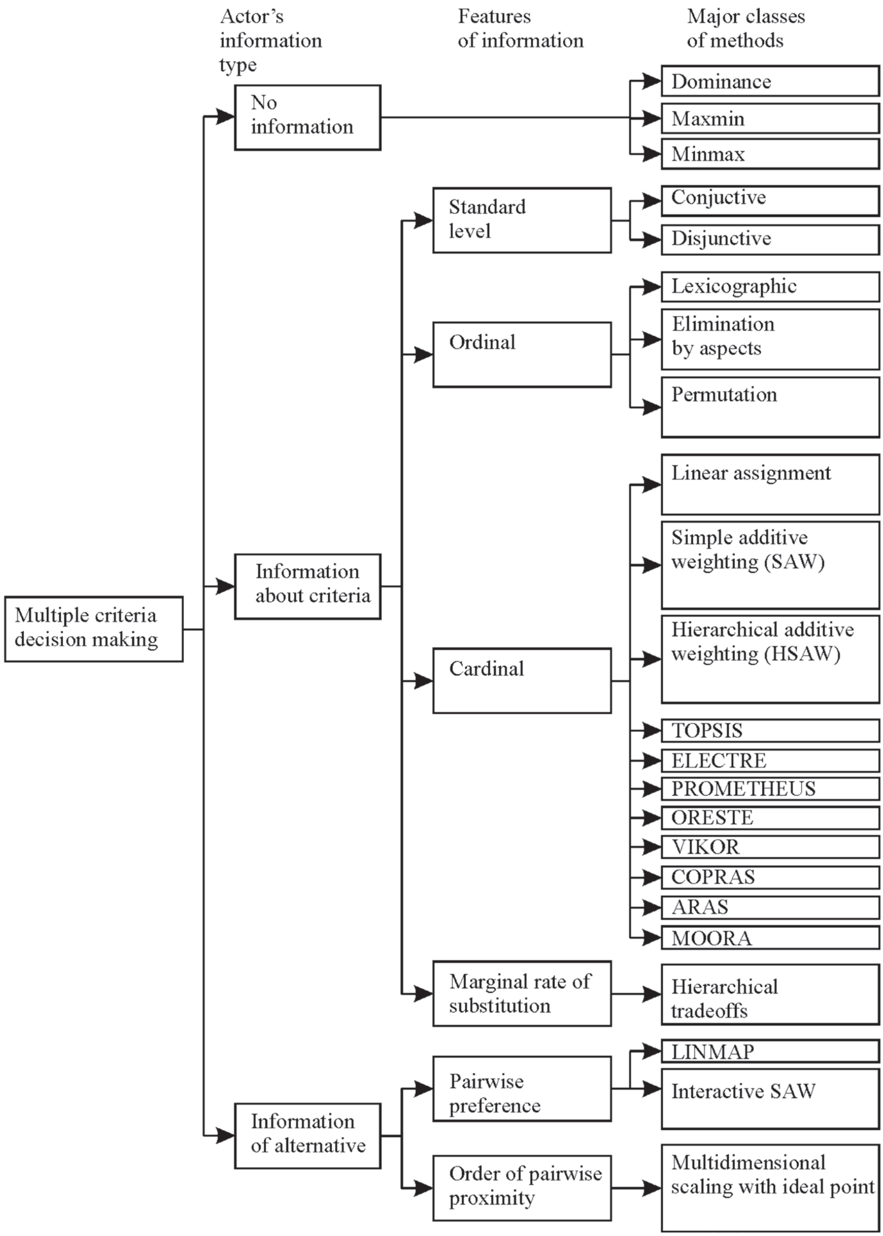


Fig. 2. Grouping of multiple criteria decision making methods (Adopted from Hwang and Yoon 1981)

some knowledge of areas generating critical situations and insolvency. It is necessary to learn the criteria determining both development and downfall of feasible alternatives (Kapliński 2008a). In a mono-criterion approach, the analyst builds a unique criterion capturing all the relevant aspects of the problem. Such a one-dimensional approach is an oversimplification of the actual nature of the problem. In many real-world decision problems, the decision-maker has a set of multiple conflicting objectives. All new ideas and possible variants of decisions must be compared according to many criteria (Turskis *et al.* 2009). The problem of decision-maker consists of evaluating a finite set of alternatives in order to find the best one, to rank them from the best to the worst, to group them into predefined homogeneous classes, or to describe how well each alternative meets all the criteria simultaneously. There are many methods for determining the ranking of a set of alternatives in terms of a set of decision criteria.

Over the past decades the complexity of economical decisions has increased rapidly, thus highlighting the importance of development and implementation of sophisticated and efficient quantitative analysis techniques for supporting and aiding economical decision-making. MCDM is an advanced field of OR; it provides decision makers and analysts with a wide range of methodologies, which are overviewed and well-suited to the complexity of economical decision problems (Hwang and Yoon 1981; Zopounidis and Doumpos 2002; Figueira *et al.* 2005). Over the last decade scientists and researchers have developed a set of new MCDM methods (Kaplinski and Tupenaite 2011; Kapliński and Tamosaitiene 2010; Tamosaitiene *et al.* 2010). They modified methods and applied to solve practical and scientific problems.

Most of MCDM methods deal with discrete alternatives, which are described by a set of criteria. Criteria values can be determined as a cardinal or ordinal information. Information could be determined exactly or could be fuzzy, determined in intervals. Modern MCDM methods enable decision makers to deal with all above mentioned types of information. One of the problems encountered during multiple criteria decision making process is the choice of the aggregation procedure for solving the decision problem. However, multiple criteria decision analysts provide a variety of aggregation procedures. MCDM methods have become increasingly popular in decision making for economics because of the multi-dimensionality of the sustainability goal and the complexity of socio-economic, environment and government systems (Tables 1 and 2). Approximately one out of six scientific researches in MCDM deal with fuzzy sets or fuzzy relations (Table 2, Fig. 3).

In the multiple criteria approach, the analyst seeks to build several criteria using a few points of view. MCDM is one of the most widely used decision methodologies in science, business, and governmental worlds, which are based on the assumption of a complex world, and can help improve the quality of decisions by making the decision making process more explicit, rational, and efficient. In real life, a decision-maker first of all must understand and describe the situation. This stage includes the determination and assessment of the stakeholders, different alternatives of feasible actions, a large number of different and important decision criteria, type and quality of information, etc. It appears to be the key point defining MCDM as a formal approach. For Zeleny (1977, 1982) decision criteria are rules, measures and standards that guide decision-making. Bouyssou (1990) proposed a general definition of a criterion as a tool allowing comparison of alternatives according to a particular point of view. When building a criterion, the analyst should keep in mind that it is necessary for all the actors of the decision process to adhere to the comparisons that will be deduced from that model. Criteria (relatively precise, but usually conflicting) are measures, rules and standards that guide decision-making, which also incorporates a model of preferences between elements of a set of real or fictitious actions. Typical examples of MCDM problems are referred to as discrete MCDM problems, involve the selection among different investment projects, personnel ranking problem, and financial classification problem, and are decision-support oriented. The major strength of multiple criteria methods is their ability to address to the problems marked by various conflicting interests.

Table 1. Dynamics of multiple criteria decision making applications in economics (this table is based on the search in sciencedirect.com accessed on 9 May 2011)

Year of publication	Decision-making & economics (keywords)							Total B-G
		& multiple criteria	& multicri-teria	& multiat-tribute	& multiple attribute	& multiple objectives	& multi-objective	
	A	B	C	D	E	F	G	
2011	6688	2280	358	110	4177	8429	453	15807
2010	9694	3119	316	101	5945	12165	497	22143
2009	8965	2870	262	99	5448	11441	451	20571
2008	8264	2498	242	89	4990	10185	375	18379
2007	7284	2260	182	70	4617	9197	364	16690
2006	6416	1866	123	51	3856	8054	280	14230
2005	5294	1494	125	60	3048	6562	228	11517
2004	5266	1360	102	55	2881	5953	193	10544
2003	4510	1164	88	43	2468	5056	164	8983
2002	3760	992	88	55	1956	4121	132	7344
2001	3645	916	68	41	1839	3838	127	6829
2000	3165	788	52	50	1638	3380	135	6043
1999	2796	691	73	54	1441	3000	119	5378
1998	2879	724	79	71	1416	2968	142	5400
1997	2763	649	74	70	1297	2688	151	4929
1996	2668	641	77	90	1203	2520	180	4711
1996	2562	565	68	59	1133	2246	140	4211
1994	2300	515	36	47	1052	2079	165	3894
1993	1979	433	59	50	888	1835	132	3397
≤1992	21914	4170	370	356	8708	17773	1101	32478
Total	112812	29995	2842	1621	60001	123490	5529	223478

Dynamics of publications (B-G)

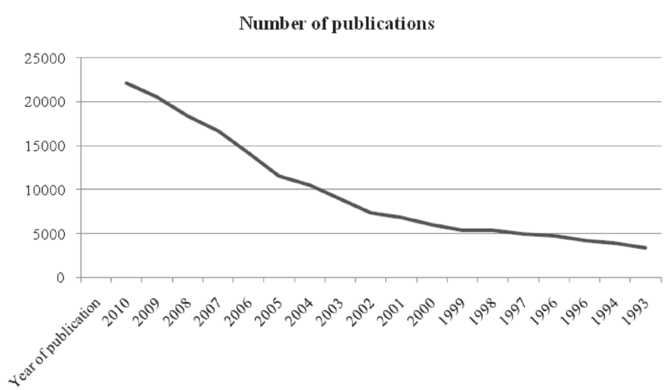
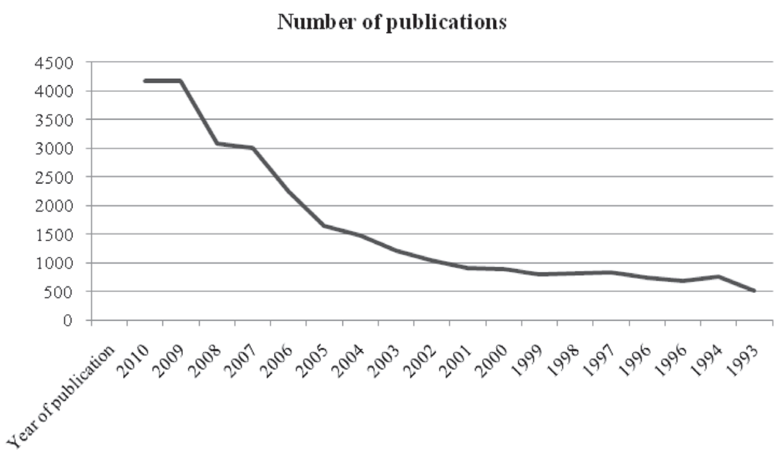


Table 2. Dynamics of fuzzy multiple criteria decision making applications in economics (this table is based on the search in sciencedirect.com (accessed on 9 May 2011))

Year of publication	Decision making (fuzzy) economics (keywords)							Total B-G
		multiple criteria	multi-criteria	multi-attribute	multiple attribute	multiple objectives	multiobjective	
	A	B	C	D	E	F	G	
2011	733	1200	335	91	856	1179	233	3894
2010	827	1295	344	91	885	1315	238	4168
2009	843	1293	325	70	931	1306	242	4167
2008	601	936	288	54	666	952	178	3074
2007	538	941	278	60	614	926	179	2998
2006	432	702	214	57	450	695	139	2257
2005	322	530	128	32	338	525	99	1652
2004	248	466	122	39	292	475	84	1478
2003	200	381	101	25	257	377	68	1209
2002	159	332	77	28	202	339	58	1036
2001	163	293	68	25	182	288	55	911
2000	156	283	82	19	172	281	55	892
1999	121	252	72	17	164	255	41	801
1998	139	241	88	23	145	252	65	814
1997	111	250	91	37	175	232	55	840
1996	127	238	62	28	137	234	53	752
1996	136	209	68	34	138	190	48	687
1994	120	224	63	35	138	224	73	757
1993	80	173	40	13	93	157	48	524
≤1992	745	1244	394	159	777	1151	282	4007
Total	6801	11483	3240	937	7612	11353	2293	36918

Dynamics of publications (B-G)



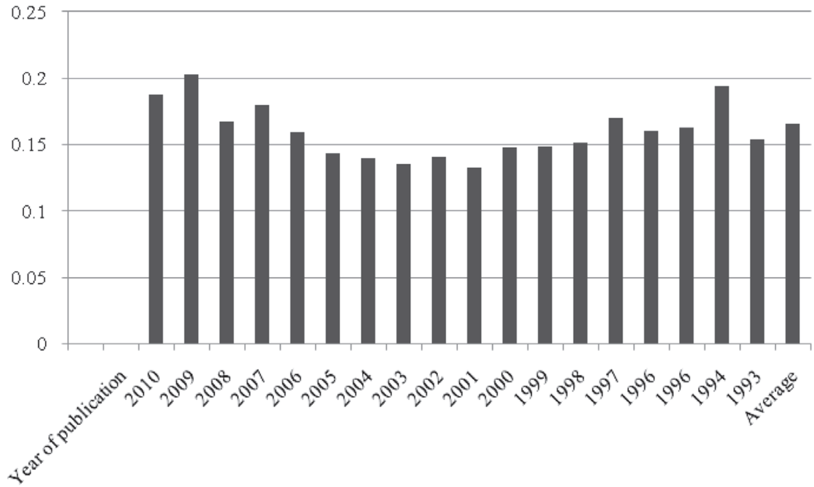


Fig. 3. Part of fuzzy multiple criteria decision making models in scientific researches of economics (ratio number of fuzzy decision making models to total number of decision making models)

Classical methods of multiple criteria optimization and determination of priority and utility function were first applied by Pareto in 1896 (Pareto 1971). These methods were strongly related to economical theory, concerning the averages of thousands of decisions. Methods of multiple criteria analysis were developed to meet the increasing requirements of human society and the environment. Methods of multiple criteria analysis were developed in 1960s to meet the increasing requirements of human society and the environment. Keeney and Raiffa (1976) offered the representation theorems for determining multiple criteria utility functions under preferential and utility independence assumptions. Keeney (1982) outlined the essential features and concepts of decision analysis, formulated axioms and major stages. Seo (1981) suggested a multiple criteria decision making method that was concerned with balancing some conflicting objectives in a hierarchical structure. Saaty (1977) showed the global importance of solving problems with conflicting goals by using multiple criteria models and presented decision making models with incomplete information. In his latest works Saaty (Saaty *et al.* 2003) analyzed measuring problems in assignments associated with uncertainty conditions and applied the AHP method to solve different problems. Tanino *et al* (1981) analyzed the problem of the coordination of different goals and objectives of various interested parties. Keeney (1982) outlined the essential features and concepts of decision analysis, formulated axioms and major stages. Keeney and Winterfeldt (2001) suggested following the prudence principle in decision process, making decisions precisely and evaluating all possible alternatives, the aims of interested parties, subsequences of decision results and value changes, hereby minimizing the decision making risk.

There are lot of even sophisticated issues in collaboration with specialists representing other domains of science (e.g. mathematicians) (Kapliński 2008a, b, c). Available wide range of MCDM problems solution techniques, varying complexity and possibly solutions, confuses potential users. Each method has own strengths, weaknesses and possibilities to be applied.

It causes phenomena known as the inconsistent ranking problem and can be caused by different MCDM methods. A major criticism of MCDM methods is that due to the differences among different techniques, different results are obtained when applied to the same problem. These differences of algorithms are:

- Using weights differently;
- Different selection of the best solution;
- Attempt to scale objectives;
- Introducing additional parameters that affect solution.

The need of comparing MCDM methods and the importance of the selection problem were first recognized by MacCrimmon who suggested taxonomy of MCDM methods. There are many comparative studies presented in scientific research works. Guitoni and Martel (1998) proposed a methodological approach to select an appropriate MCDM method to a specific decision making situation. The selection may be done via comparing MCDM methods (Zanakis *et al.* 1998). A simulation by Zanakis *et al.* (1998) evaluated eight MCDM methods: SAW, multiplicative exponential weighting (MEW); ELECTRE, and AHPs: SAW and MEW performed best. Computations of different examples reveal the fact that evaluation outcome depends on both choice of utility function and its parameters (Podvezko and Podviezko 2010).

There are many ways to classify MCDM methods (Hwang and Yoon 1981; Larichev 2000; Figueira *et al.* 2005). For instance, Belton and Stewart (2002) offered the following classification of MCDM methods: 1) value measurement models; 2) goal, aspiration, and reference level models; 3) outranking models (the French school).

The classification of MCDM methods according to the type of information based on the Larichev's (Larichev 2000) proposal is given bellow:

- Methods based on quantitative measurements. The methods based on multiple criteria utility theory may be referred to this group (TOPSIS, LINMAP, MOORA, COPRAS, and its modification COPRAS-G).
- Methods based on qualitative initial measurements. These include two widely known groups of methods: AHP and fuzzy set theory methods (Zimmermann 2000).
- Comparative preference methods based on pair-wise comparison of alternatives. This group comprises the modifications of the ELECTRE, PROMETHEE, TACTIC, ORESTE and other methods (Turskis 2008).
- Methods based on qualitative measurements not converted into quantitative variables. This group includes methods of verbal decision making analysis (Berkeley *et al*. 1991) and uses qualitative data for decision environments involving high levels of uncertainty.
- MCDM problems can be categorized as continuous or discrete, depending on the domain of alternatives.

Hwang and Yoon (1981) classify them as:

- MCDM with discrete, usually limited, number of alternatives, requiring criterion comparisons, involving implicit or explicit tradeoffs;
- MODM (multiple objective decision-making), with decision variable values to be determined in a continuous or integer domain, of infinite on a large number of choices, to satisfy best the decision-maker constraints, preferences or priorities.

In particular, the main steps of multiple criteria decision making are the following:

– Determining the main goal of a problem;
– Establishing system of the main objectives or criteria by which the alternatives are to be judged;
– Generating feasible alternatives (a finite number of alternative plans or options) that can be implemented to achieve goals;
– Evaluating an impact of each criterion on the decision making function or weights of criteria. A decision-maker should express his / her preferences in terms of the relative importance of criteria, and one approach is to introduce criteria weights.

The weights in MCDM do not have a clear economic significance, but their use provides opportunity to model actual aspects of the preference structure:

– A set of performance evaluations of alternatives for each criterion;
– A method for ranking the alternatives based on how well they satisfy the criteria;
– Aggregating alternative evaluations (preferences);
– Accepting one alternative as the best (the most preferable);
– Gathering new information and the next iteration of MCDM if the final solution is not accepted;
– Making recommendations for decision-making.

An alternative in multiple criteria evaluation is usually described by quantitative and qualitative criteria. The criteria have different units of measurement. Normalization aims at obtaining comparable scales of the criteria values. Different techniques of criteria value normalization are used. The impact of the decision-matrix normalization methods on the decision results has been investigated by many authors (Jüttler 1966; Körth 1969; Stopp 1975; Weitendorf 1976; Zavadskas 1987, 1990; Peldschus 2009; Ginevičius 2008; Zavadskas and Turskis 2008). There are still no rules determining the application of multiple criteria evaluation methods and interpretation of the results obtained.

The case study findings about pioneering studies in multiple criteria decision making paradigms and earliest application are summarized in Table 3.

5. Recent development and applications

Recent case study findings about the parallels between economics and multiple criteria decision making paradigms are summarized in Table 4. There, it is pointed at the methods applied by users except for authors of the paper. Authors of paper applied most of the methods listed in Table 4 in own researches, but they have not presented them.

6. Conclusions

Operations research is very beneficial in deciding upon what to produce, the quantities, the methods of production, which employees to engage in the production processes and the marketing schemes of the produced goods. In this survey a comprehensive view of problems that are open in the field of decision making in economics is given.

The fact that people act rationally and are independent of personal emotions, feelings, instincts or culturally specific, moral codes and norms has been recognised by many scientists in classical theories. It is evident that no human has ever satisfied this criterion. Groups and organisations, business enterprises, and others may, then, all figure as collective actors whose individual intentions are aggregated and an agreed policy formulated. There could be definitely stated that the "best" approach does not exist. The eventual choice of one is a multiple criteria problem and, therefore, it has no optimal solution. Economical decision making is extremely complex due to the intricacy of the systems considered and the competing interests of multiple stakeholders. Decision making theories and applications offer different modelling techniques, provide an appropriate approaches for modelling decision aiding, help in development of alternatives as they take into account the complexity of the process.

The selection of a model and problem solution approach depends on the desired goal, actors involved in the decision making process, available information, time, and etc. There are several branches of decision theory that depart from the stand expected utility paradigm. The major strength of multiple criteria methods is their ability to address problems marked by various conflicting interests.

There are a lot of open fields of future research as:

- Analysis of different scaling methods;
- Analysis of preference relations;
- Analysis of aggregation procedures;
- The study of grey relations;
- The study of fuzzy relations;
- The development and modification of new mathematical models to solve outranking problems.

Multiple criteria decision making provides powerful approaches to solve complicated problems in economics. These techniques allow actors to solve those problems which are impossible to solve by applying common optimisation models.

The main focus of this paper was to overview the use of decision support tools, such as recent developments of classical models of multicriteria decision analysis, which are being used increasingly for comparative analysis and assessment of alternatives.

Table 3. Backgrounds of multiple criteria decision making approaches and the earliest applications

	Methods	Studies
Multiple attribute utility theory (MAUT)		Keeney and Raiffa (1976)
	LOGICAL DECISION	Smith and Speiser (1991)
	DECAID	Pitz (1987)
		Вайгаускас, Завадскас (1980)
	Simple Additive Weighting (SAW)	MacCrimon (1968)
	Linear Programming Techniques for Multidimensional Analysis of Preference (LINMAP)	Srinivasan and Shocker (1973)
	Analytic Hierarchy Process (AHP)	Saaty (1977, 1980);
	Analytic Hierarchy Process (AHP)	Lootsma (1993)
	Utility Theory Additive (UTA)	Jacquet-Lagréze and Siskos (1982)
	TOPSIS	Hwang and Yoon (1981)
	TOPSIS	Antuchevičienė *et al.* (2010)
	Multicriterion Analysis of Preferences by means of Pairwise Alternatives and Criterion comparisons (MAPPAC)	Matarazzo (1986, 1988b)
	PRAGMA	Matarazzo (1988a, 1988b)
	Measuring Attractiveness by a Categorical Based Evaluation TecHnique. (MACBETH)	Bana e Costa and Vansnick (1994)
	Complex Proportional Assessment (COPRAS)	Zavadskas and Kaklauskas (1996)
	Complex Proportional ASsessment method with Grey interval numbers (COPRAS-G)	Zavadskas *et al.* (2008)
	REMBRANDT	Lootsma (1992) Olson *et al*. 1992
	Multi-Objective Optimization by Ratio Analysis Method (MOORA)	Brauers and Zavadskas (2006)
	MULTIMOORA	Brauers and Zavadskas (2010)
	Additive Ratio Assessment method (ARAS)	Zavadskas and Turskis (2010)
	ARAS-F	Turskis and Zavadskas (2010a)
	ARAS-G	Turskis and Zavadskas (2010b)
	Step-wise weight assessment ratio analysis (SWARA)	Keršuliene *et al.* (2010)
Outranking relations	ELimination Et Choix Traduisant la REalité (ELimination and Choice Expressing REality) (ELECTRE)	Benayoun *et al.* (1966) Roy (1968, 1991) Roy (1978, 1990, 1996)
	ELECTRE III and IV	Vallée and Zielniewicz (1994)
	Organization, Rangement Et Synthese de dones relaTionnElles (ORESTE)	Roubens (1982)
	Preference Ranking Organization Method for Enrichment Evaluation (PROMETHEE)	Brans *et al.* (1984, 1986)
		Brans and Mareschal (1992)
		Zahedi (1986)
	MELCHIOR	Leclercq (1984)
	Tratement des Actions Compte Tenu de l'Importance des Crite'res (TACTIC)	Vansnick (1986)
	ARGUS	De Keyser and Peters (1994)
	VIP	Dias and Clķmaco (2000)
	IRIS	Dias *et al.* (2002)
	Compromise ranking method (VIKOR)	Opricovic (1998)

Comments
Background MAUT
Decision support system based on the MAUT
Decision support system based on the MAUT
Investigation of MAUT practical applications
Author
Authors
Author of AHP
Multiplicative AHP is an exponential version of the simple multi-attribute rating technique (SMART)
Authors
Authors
The case study proved that the proposed TOPSIS-M (TOPSIS applying Mahalanobis distance measure)
Author
Author
Authors
Authors
Authors. Ranking of alternatives
Author Users
Authors
Authors. Full Multiplicative Form is added to MOORA.
Authors of new method
Authors. Fuzzy set applied to location problem. ARAS-F presented
Authors. Grey relations applied to problem solution. ARAS-G presented
Selection of rational dispute resolution method by applying new step-wise weight assessment ratio analysis
First publication Author Explains the bases of general decision making methodology which took shape toward end of 1960s. The evolutions have continued with ELECTRE II, ELECTRE III, ELECTRE IV, ELECTRE IS and ELECTRE TRI.
Practical realization, provided with software
Author
Authors
PROMETHEE V method presented
Reviewed the AHP and its applications in diverse decision problems. It addresses some of the major extensions and criticisms of the method, as well.
Authors
Author
Author
Analysis software. Authors
Analysis software. Authors
Author

Table 4. Recent applications of multiple criteria decision making approaches in economics

Method	Reference	Considered problem
AHP	Ananda and Herath (2008)	AHP is used to synthesise stakeholder preferences related to regional forest planning and to incorporate stakeholder preferences.
	Cebeci (2009)	Presented an approach to select a suitable enterprise resource planning system for textile industry. Fuzzy AHP method is applied.
	Wu *et al*. (2009)	Fuzzy AHP (FAHP) and the three MCDM analytical tools of SAW, TOPSIS, and VIKOR were respectively adopted to rank the banking performance and improve the gaps with three banks.
	Podvezko (2009)	Application of AHP technique to more complicated cases is considered
	Colombo *et al*. (2009)	Proved that judicious use of AHP by experts can, in this instance, be used to represent citizens' views.
	Maskeliūnaitė *et al*. (2009)	Problem of quality of passenger carriage
	Podvezko *et al*. (2010)	Contracts' ranking
	Štemberger *et al*. (2009)	Applied in business processes management.
	Sivilevičius and Maskeliūnaitė (2010)	Problem of improving the quality for passenger transportation
	Bojovic *et al*. (2010)	Determination of an optimal rail freight car fleet composition
	Steuten *et al*. (2010)	AHP weights are used to fill missing gaps in Markov decision models.
	Hadi-Vencheh and Niazi-Motlagh (2011)	An improved voting AHP-data envelopment analysis methodology for suppliers selection
	Yan *et al*. (2011)	Presented new developments and maintenances of the existing infra-structures under limited government budget and time
UTA	Gomes and Rangel (2009)	An application of the UTA method and its variant UTA-CR to determine utility functions for the multiple criteria evaluation of residential real estate.
COPRAS	Ginevičius and Podvezko (2008)	Evaluation of banks from the Perspective of their reliability for clients
	Datta *et al*. (2009)	Determining compromise towards the selection of supervisor
	Bindu Madhuri *et al*. (2010)	Selection of alternatives based on COPRAS-G and AHP methods
	Uzsilaityte and Martinaitis (2010)	Comparison of different alternatives for the renovation of buildings, taking into account energy, economic and environmental criteria while evaluating impact of renovation measures during their life cycle
	Chatterjee *et al*. (2011)	Material selection based on COPRAS and EVAMIX methods
	Karbassi *et al*. (2011)	Effectiveness problem of energy using in buildings
	Podvezko (2011)	The Comparative Analysis of MCDA Methods SAW and COPRAS

Method	Reference	Considered problem
TOPSIS	Jakimavičius and Burinskiene (2007)	Developed approach of automobile transport system analysis
TOPSIS	Arslan and Aydın (2009)	Two real military problems are solved by an ideal point algorithm and an outranking method. Fuzzy sets are applied.
TOPSIS	Jakimavičius and Burinskienė (2009)	Computed ranks for transport zones of city according to accessibility and city statistics
TOPSIS	Liaudanskienė *et al.* (2009)	Selection of the most effective alternative in construction
TOPSIS	Wu *et al.* (2009)	Fuzzy AHP (FAHP) and the three MCDM analytical tools of SAW, TOPSIS, and VIKOR were respectively adopted to rank the banking performance and improve the gaps with three banks.
TOPSIS	Liu (2009)	Explored the multi-attribute decision making problem based on the interval vague value
TOPSIS	Čokorilo *et al.* (2010)	Determining the optional solution from the existing fleet
TOPSIS	Rudzianskaitė-Kvaraciejienė *et al.* (2010)	The problem of selecting the most effective road investment projects.
TOPSIS	Ginevičius *et al.* (2010)	Formation of the integrated competitive strategy of an enterprise under the conditions of oligopoly market. SAW, VIKOR and TOPSIS are used.
TOPSIS	Jin and Liu (2010)	The extended TOPSIS method is proposed to solve multi-attribute group decision making problems when the attribute values take the form of interval grey linguistic variables and attribute weight is unknown.
TOPSIS	Liu and Liu (2010)	A relative approach degree method of grey relation projection is presented to deal with multiple attribute making, in which the attribute weight is unknown and attribute value is hybrid index.
TOPSIS	Han and Liu (2011)	Modified fuzzy TOPSIS is applied
ARAS	Bakshi and Sarkar (2011)	Performance evaluation of project
ARAS	Baležentis and Baležentis (2011)	Integrated assessment of economic sectors
SAW	Jakimavičius and Burinskienė (2007)	Developed mechanism of automobile transport system analysis
SAW	Žvirblis and Zinkevičiūtė (2008)	Integrated evaluation of the macro environment of freight transportation companies was conducted
SAW	Jakimavičius and Burinskienė (2009)	Computed ranks for transport zones of city according to accessibility and city statistics
SAW	Shevchenko *et al.* (2008)	Comparative analysis (CLARA and SAW methods) of variants of investment classified risks
SAW	Wu *et al.* (2009)	Fuzzy AHP (FAHP) and the three MCDM analytical tools of SAW, TOPSIS, and VIKOR were respectively adopted to rank the banking performance and improve the gaps with three banks.
SAW	Žvirblis and Buračas (2010)	Research and evaluation of State financial markets
SAW	Ginevičius *et al.* (2010)	Forming the integrated competitive strategy of an enterprise under the conditions of oligopoly market. SAW, VIKOR and TOPSIS are used.
SAW	Podvezko (2011)	The Comparative Analysis of MCDA Methods SAW and COPRAS

Method	Reference	Considered problem
ELECTRE	Thiel (2008)	Peculiarities of method applying
	Ulubeyli and Kazaz (2009)	Selection problem
	Radziszewska-Zielina (2010)	Partner selection problem
	Wachowicz (2010)	ELECTRE-TRI method applied. Two authors introduced their own procedures that can be applied in the pre-negotiation phase for eliciting negotiators' preferences and building the offer scoring systems for the parties.
	Bojković *et al.* (2010)	Transport as an economic activity having complex interactions with the environment was investigated.
	Kaya and Kahraman (2011)	AHP and ELECTRE methods applied to assessment of E-banking Sector
PROMETHEE	Nowak (2005)	Investment evaluation
	Mitkova and Mlynarovic (2007)	The results from two methodological approaches to the analysis of performance and risk of private pension funds in the Slovak Republic are presented: (1) multiple criteria decision model, and PROMETHEE methodology, (2) modern portfolio theory to analyze pension funds in a risk-return space.
	Palma *et al.* (2007)	Multi-criteria analysis was used to evaluate the integrated performance of silvoarable agro forestry on hypothetical farms in nineteen landscape test sites in Spain.
	Ghazinoory *et al.* (2009)	Different areas of nanotechnology for Iranian economy considering other countries' strategies and the results of PROMETHEE method are prioritized.
	Tomić-Plazibat *et al.* (2010)	Assessed country-risk of sixteen Central, Baltic and South-East European transition countries, for 2005 and 2007, using multivariate cluster analysis.
	Podvezko and Podviezko (2010)	Reveals influence of the choice of preference functions and their parameters on the outcome of evaluation
	Juan (2010)	Porter's diamond model of competitive advantage is applied to establish evaluating criteria on urban competitiveness quality, and a fuzzy set theory combining the PROMETHEE method is used to determine the priority of projects.
MOORA	Brauers and Ginevičius (2009)	Robustness in regional development
	Brauers *et al.* (2010)	Assessment of regional and international development
	Brauers and Zavadskas (2010)	Example of project management under multiple objectives and MULTIMOORA is presented.
	Ivanov and Stanujkić (2010)	Software selection
	Brauers and Ginevičius (2010)	The economy of the Belgian regions is tested with MULTIMOORA
	García Alcaráz *et al.* (2010)	Evaluation of feasible alternatives and selection problem
	Chakraborty (2011)	Applications of the method in manufacturing environment
	Brauers *et al.* (2011)	MULTIMOORA with fuzzy number theory applied to EU member states assessment

Method	Reference	Considered problem
VIKOR	Ginevičius and Podvezko (2006)	Evaluated financial state of enterprises from various perspectives
	Antucheviciene and Zavadskas (2008)	Modelling multidimensional redevelopment of derelict buildings. Fuzzy VIKOR is applied.
	Wu *et al.* (2009)	Fuzzy AHP (FAHP) and the three MCDM analytical tools of SAW, TOPSIS, and VIKOR were respectively adopted to rank the banking performance and improve the gaps with three banks.
	Ginevičius *et al.* (2010)	Forming the integrated competitive strategy of an enterprise under the conditions of oligopoly market. SAW, VIKOR and TOPSIS are used.
Game theory	Ginevičius and Krivka (2008)	Duopoly market analysis
	Zavadskas and Turskis (2008)	Peculiarities of problem solution
	Stein (2010)	Determined agents' strategies based on intended but bounded rationality
	Stein and Ginevičius (2010)	Presented round based games in which the present values change and influence the cooperative relationships
	Kapliński and Tamošaitienė (2010)	Game theory applications for management problems solution

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DAUGIATIKSLIAI SPRENDIMŲ PRIĖMIMO METODAI EKONOMIKOJE: APŽVALGA

E. K. Zavadskas, Z. Turskis

Santrauka. Priimant ekonominius sprendimus pagrindinis tikslais gali būti: įvertinti tikslingas altrenatyvas, parinkti geriausią alternatyvą, įgyvendinti parinktą sprendimą ir gauti didžiausią naudą. Sprendimus gali parinkti tiek atskiri veikėjai tiek ir veikėjų grupės. Vertinamų sprendimų pasekmės įtakoja tiek sprendėjų tiek ir visuomenės poreikius. Šiame straipsnyje pateikiama sprendimų priėmimo metodų, kuriuos galima taikyti ekonomikoje, apžvalga. Straipnyje pateikiama paskutinių penkerių metų svarbiausių tyrimų apžvalga. Taip pat pristatyti populiariausių daugiatikslių sprendimų priėmimo metodų, kurie taikomi ir kuriuos galima taikyti priimant sprendimus ekonomikoje, autoriai.

Reikšminiai žodžiai: daugiatikslis sprendimų priėmimas, ekonomika, analizė, apžvalga.

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