Multiple criteria decision making in supply chain management – Currently available methods and possibilities for future research

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Literature review, Supply chain management, Multiple criteria decision making, Multi-attributive utility theory

Entscheidungen im Supply Chain Management (SCM) unterliegen einer Reihe von konfliktären Kriterien und müssen mehrere Ziele im Entscheidungsprozess berücksichtigen. Des Weiteren ist meist eine Gruppe von Entscheidern in den Prozess eingebunden, anstelle eines einzelnen Entscheidungsträgers. Für derartige Entscheidungen sind multikriterielle Entscheidungsverfahren geeignet. Gegenwärtig ist jedoch kein Überblick über die Anwendung multikriterieller Entscheidungsverfahren im SCM verfügbar. Dieser Aufsatz führt eine Literaturrecherche durch, um diese Lücke zu schliessen und einen Überblick über die Anwendung multikriterieller Entscheidungsverfahren im SCM zu geben. Wir kategorisieren 124 Aufsätze nach Anwendungsbereichen in SCM, angewandte Methoden, Zeitschriften, Jahr der Veröffentlichung, und prüfen, ob die Aufsätze einen Gruppenentscheidungs-Ansatz integrieren oder empirische Belege nutzen. Ein zentrales Ergebnis ist das kräftige Wachstum der multikriterieller Entscheidungsverfahren im SCM in den letzten sechs Jahren, das sich voraussichtlich in Zukunft fortsetzen wird. Darüber hinaus ist der SCM-Anwendungsbereich Einkauf bereits gut abgedeckt, im Gegensatz zu dem SCM-Anwendungsbereich Distribution. Der akademische und praktische Beitrag des Aufsatzes liegt in der Übersicht multikriterieller Entscheidungsverfahren für SCM-Entscheidungsprobleme. Ausserdem präsentieren wir potenzielle Bereiche für die zukünftige Forschung zu multikriteriellen Entscheidungsverfahren im SCM.

Decisions in supply chain management (SCM) are subject to various conflicting criteria and multiple objectives must be considered in the decision process. Furthermore, a group, rather than a single decision maker, is often involved in the process. For such decisions, methods in multiple criteria decision making (MCDM) are certainly appropriate. However, an overview concerning applications of MCDM methods in SCM is not yet available. This paper conducts a literature survey to fill this gap and give an overview of MCDM applications in SCM; a research map is developed to guide researchers interested in this field. We categorize 124 reviewed articles according to application areas in SCM, applied methods, journals, publication year and we ascertain whether the papers incorporate a group decision approach or use empirical support for the MCDM application. A

central review finding is the strong growth of MCDM applications in SCM in the last six years, expected to continue in the future. In addition, the application area purchasing is already well covered, contrary to the application area distribution. This article's contribution to academia, as well as business practice, is represented in the MCDM methods overview, currently available for SCM decision problems. We also present potential areas for future research.

1. Introduction

A properly functioning supply chain management (SCM) is crucially important in dealing with dynamically changing customer requirements. In fact, in the current business environment, whole supply chains are competing with each other instead of single companies (cf. *Li* 2002; *Ha/Tong* 2008). While earlier research in SCM was mostly efficiency driven, the focus today moves to effectiveness issues and a stronger customer orientation (cf. *Zokaei/Hines* 2007; *Godsell et al.* 2011). SCM developed from a subject of operational and tactical consideration to a strategic topic within management research and business practice (cf. *Melnyk et al.* 2009; *Hofmann* 2010).

As the importance of certain management areas increases, the need for suitable decision support in these areas also rises. Decision problems in SCM range from single quantitative criterion analyzes to multiple criteria and/or objectives problems, where quantitative as well as qualitative criteria must be incorporated. A very common decision problem in SCM is the single-criterion, purely quantitative consideration of inventory control. For such problems, classical methods only consider costs and minimize them under certain constraints, like customer service. However, even in such cases, authors tend to state that conflicting goals are balanced (cf. *Axsäter* 2006). An extension of this problem would be the introduction of a second objective, e.g. simultaneous minimization of costs and maximization of customer service, a bi-objective problem. One SCM problem is supplier selection; its complexity and importance for manufacturers, requires consideration of several conflicting quantitative and qualitative criteria (cf. *Wu et al.* 2010). Such problems often include objectives like maximizing quality and reliability of the supplier, while minimizing cost and risk linked to the sourced item. All of the decision problems above have a tremendous impact on the success of single companies and whole supply chains. Incorrect decisions may cause decreasing competitiveness or even the collapse of companies or whole supply chains. Due to the importance and impact of correct decisions within SCM, suitable decision support for different decision problems in SCM is relevant and should not be neglected by academia.

Regarding optimization problems, there are many academic contributions about applications of such methods in SCM or topics relevant to SCM. These papers include applications for operative and tactical problems like production and transportation planning, as well as utilization in strategic context, e.g. supply chain network design. These optimization approaches ensure optimal solutions for the considered objective functions and may save money for the company or ensure flexibility in customer service. Several literature reviews give a comprehensive overview of these applications (e.g. *Tamiz et al.* 1998; *Meixell/Gargeya* 2005; *Melo et al.* 2009; *Mula et al.* 2010).

However, many strategic decisions are not subject to optimization, as they involve multiple imprecise, uncertain and qualitative criteria. MCDM offers support for such strategic decisions (cf. *Montibeller/Franco* 2011), allowing for the consideration of conflicting and

qualitative objectives (cf. *Ram et al.* 2011). *Wallenius et al.* (2008) state that the most crucial support delivered by MCDM approaches to decision makers is probably the structured examination of the decision problem as part of the process. While many applications of such methods to SCM already exist, a literature survey of MCDM methods, allowing the consideration of qualitative information in SCM, is not available yet.

This paper aims to close this gap through a structured literature survey. We answer two research questions (RQs):

RQ1: Which supply chain management application areas are covered by suitable multiple criteria decision making approaches?

RQ2: What multiple criteria decision making trends may develop in supply chain management?

To answer these questions, we analyze academic peer-reviewed articles, published from 2000 to 2011. We use the literature platforms EBSCO HOST (Business Source Premier) and ABI/INFORM Complete. 334 papers match our search terms and 124 are relevant to the considered topic. We analyze the identified papers within the SCM application areas design, purchasing, manufacturing, distribution, collaboration, logistics, and performance management, deriving research gaps in different SCM application areas. Future trends of MCDM in SCM are deduced through current trends in SCM and in MCDM research, yielding promising prospective research fields.

In the following section, we give a general overview of MCDM. Section three presents the findings of our literature study, first a general description of the development of MCDM in SCM in the considered time frame. The second part of section three categorizes the surveyed articles by their application area in SCM and analyzes selected approaches in detail. In section four, we discuss our findings critically and state current research gaps as well as possible future trends of MCDM in SCM. Section five summarizes our findings.

2. Multiple criteria decision making in general

2.1 Categorization of multiple criteria decision making methods

MCDM began in the 1960s. Many authors mention the contribution on goal programming by *Charnes/Cooper* (1961) as the origin of MCDM. Multi-attributive utility theory (MAUT) is sometimes referred to as another research stream of multiple criteria problems (cf. *Dyer et al.* 1992). However, other authors classify it as a method category within MCDM methods. An early contribution on MAUT is *Churchman/Ackoff* (1954). In the 1970s and '80s the research streams in MCDM and MAUT evolved in close conjunction to each other (cf. *Dyer et al.* 1992). The first conference on MCDM was organized in 1972 in South Carolina at Columbia University. A more detailed description concerning the origins of MCDM, especially historical influences, may be found in *Figueira et al.* (2005).

In categorizing different MCDM methods, there is no complete consensus between authors. However, categorizations of MCDM methods do not differ widely. Our categorization of MCDM methods follows *Figueira et al.* (2005), who distinguish multi-objective mathematical programming, multi-attributive utility theory, outranking and non-classical approaches. We chose this categorization, since it most suitably represents research streams within MCDM. An alternative to this categorization is *Wallenius et al.*

(2008) who distinguish between discrete alternative problems (finite often small number of solutions) and multiple criteria optimization (high sometimes infinite number of solutions). This classification is related to the categorization we presented; since MAUT and outranking approaches may be summarized under discrete alternative problems, the mathematical programming may be referred to as multiple criteria optimization.

Multi-objective mathematical programming (MOMP) deals with optimization problems incorporating two or more conflicting goals and is mostly concerned with quantitative or simply quantifiable information. Well-known approaches in this area are goal programming and multi-objective linear programming. Goal programming approaches are normally structured in the form of one objective function, which includes the weighting of the different goals. The accurate specification of goal criterion functions are formulated within the constraints (cf. *Steuer/Na* 2003). In multi-objective linear programming, the different objectives are each formulated as an objective function, which leads to several objective functions, each subject to optimization (cf. *Ehrgott/Wiecek* 2005). Furthermore, data envelopment analysis (DEA) is often referred to as MOMP due to its close relation to such problems (cf. *Wallenius et al.* 2008).

MAUT is a further class of MCDM methods. MAUT approaches use utility theory and apply it to problems with multiple conflicting criteria. The central idea is to create a sort of value function relating to the decision maker's preferences. In most cases, the regarded criteria are intangible or hardly quantifiable and the MAUT methods offer a way to objectify the decision maker's implicit knowledge of the problem (cf. *Dyer* 2005). The analytical hierarchy process (AHP) and the analytical network process (ANP) (*Saaty/Vargas* 2006) are, in several cases, categorized as MAUT approaches (cf. *Dyer et al.* 1992), since they basically use the preferences of the decision maker concerning solution alternatives with the background of multiple hierarchical or interdependent criteria. Further approaches often summarized under this topic are measuring attractiveness by a categorical based evaluation technique (MACBETH), simple multi attribute rating techniques (SMART), technique for order preference by similarity to ideal solution (TOPSIS) and aggregation – disaggregation methods also known as utilities additives (UTA).

Outranking is often described as the European counterpart to MAUT approaches in America (cf. *Wallenius et al.* 2008). Based on information obtained from a decision maker, preferences regarding two or more solution alternatives are derived, which admit the derivation of a ranking of the solution alternatives. Like MAUT approaches outranking methods are mainly concerned with intangible, hardly quantifiable criteria. Well-known approaches in the outranking class are elimination and choice expressing reality (ELECTRE) (see *Roy* 1991) and preference ranking organization method for enrichment evaluation (PROMETHEE) (see *Brans/Vincke* 1985).

A class of more recent MCDM methods, therefore, referred to as non-classical approaches, incorporates fuzzy set theory, grey relational analysis and choquet integrals. These approaches emerged in the last ten to 15 years and are concerned with situations where information is imprecise and uncertain. *Figure 1* summarizes the categorization with respect to MCDM approaches we utilize for this review.

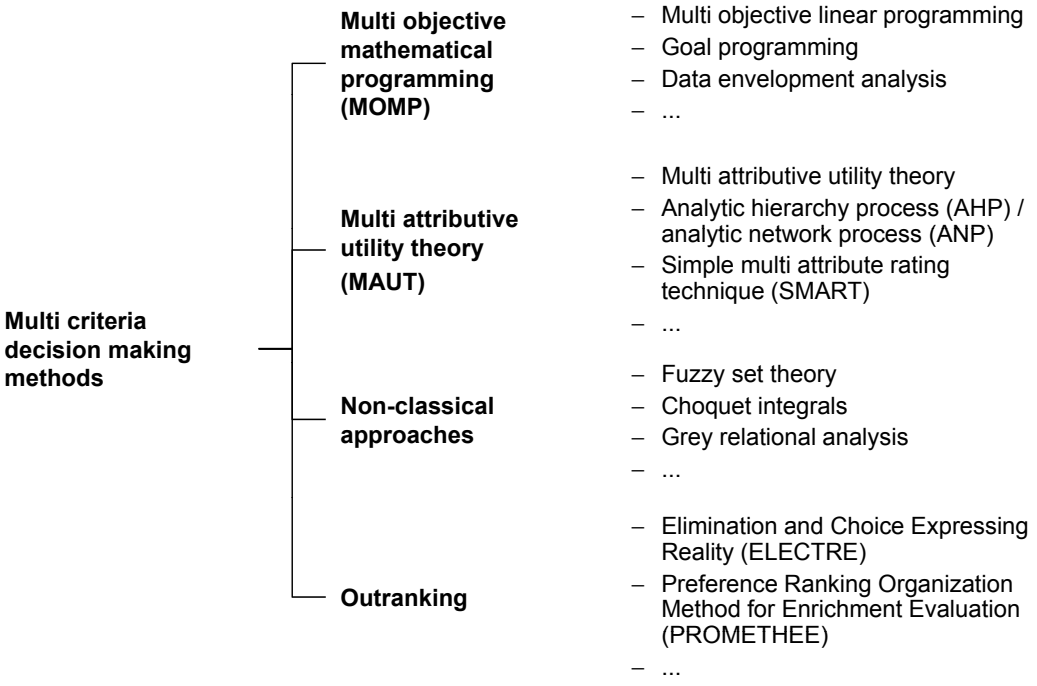

Figure 1: MCDM methods categorization

2.2 Multiple criteria decision making in other research and management disciplines

MCDM approaches are widely applied to various research areas. On the following pages, selected reviews of MCDM applications are summarized. The reviews are classifiable as: (1) general reviews that do not focus on specific methods or research areas, (2) reviews with a focus on certain methods in various research areas and (3) reviews, which focus on MCDM applications to business administration.

An early and frequently cited general review is *Dyer et al.* (1992), who discuss the state of MCDM and analyze further developments. They identify seven different areas where they expect promising future developments for methods in MCDM. *Zopounidis/Doumpos* (2002) present a general overview with respect to classification and sorting methods and their application area (e.g. medicine, human resource management or financial management and economics). The review focuses very strongly on methods and their development; the conclusions of the authors are rather technical. *Wallenius et al.* (2008) is an update of *Dyer et al.* (1992). The review contains a bibliometric analysis with respect to general applications of MCDM and shows fields for future research. They state that MCDM publications have grown by the factor 4.2 from 1992 to 2006, while the growth of science in general is estimated to have roughly increased by factor 2. In addition, they report that 34.9% of the articles included in their study are applied to operations research and management science, 23% are applied to management and business. Furthermore, they state an extraordinary increase of AHP applications in the last 20 years; in fact, AHP is the most widely applied MCDM method. *Bragge et al.* (2010) conduct a "research profiling

study" and update as well as extent the bibliometric study of *Wallenius et al.* (2008). For the analysis of more than 15,000 articles, they utilize text mining software.

In reviews with focus on specific methods, *Vargas* (1990) survey the AHP methodology and its applications to several research areas, e.g. economic and management problems, social problems as well as political problems. They find that the majority of AHP applications occur in management and economics. A further review on AHP applications is presented by *Vaidya/Kumar* (2006), who consider 150 articles and analyze 27 in detail. They classify the application problem (i.e. selection, evaluation, allocations, planning and development, medicine and related fields etc.) and the application area (i.e. social, personal, education, manufacturing, engineering etc.). Central results of their study: the AHP is heavily applied to selection and evaluation problems, in engineering and social application areas. *Ho* (2008) reviews 66 integrated AHP applications. The majority of the reviewed AHP applications relate to the logistics (21 / 66) and fields18 / 66). The primary methods applied with AHP are goal programming and quality function deployment. Furthermore, *Ho* states that in the rate of publication in the first review period (1997-2001) to the second review period (2002-2007) is 25 to 41. He assumes a further increase in integrated AHP applications in the following years. *Liberatore/Nydick* (2008) review 50 AHP applications in medical and health care. They report a steady number of applications since 1997, predominantly on evaluation problems, e.g. treatment or even capital goods selection. *Behzadian et al.* (2010) review 217 articles on the outranking method PROMETHEE, used for preference modeling. They categorize the articles with respect to their application area (e.g. environmental management, business and financial management, logistics and transport etc.) and survey occurring methodological extensions, i.e. integrated PROMETHEE applications with other MCDM methods. *Behzadian et al.* report a steady increase of PROMETHEE applications and a low rate of integrated approaches (15 of 217 applications). A further method specific review is presented *Sipahi/Timor* (2010). They survey 232 AHP/ANP applications with respect to several research areas. Like earlier studies *Spahi/Timor* state an exponential increase with respect to AHP/ANP applications and support the statement of *Ho* (2008) regarding a trend to integrated AHP approaches. The industries with the highest numbers of applications are the manufacturing industry (76 / 232) as well as environmental management and agriculture (26 / 232).

Besides the general and the methodological specific reviews, there several surveys consider MCDM applications in other management disciplines. *Steuer/Na* (2003) examine 265 MCDM applications concerning finance and related problems. They classify the reviewed studies by the applied method (e.g. goal programming, multiple objective programming, AHP etc.) and the application area (e.g. capital budgeting, working capital management, portfolio analysis, general financial planning, etc.). The bulk of contributions reviewed by *Steuer/Na* apply goal programming (103 / 265) and multiple objective programming (83 / 265). Furthermore, the top two application areas consider portfolio analysis (77 / 265) and general financial planning (45 / 265). A broad review of supplier-related topics is provided by *Jain et al.* (2009). They concentrate on areas like supplier selection, supplier-buyer relationships and supplier-buyer flexibility. Their review is not focused on MCDM applications, yet many MCDM methods are included in the articles they survey (e.g. fuzzy set theory, AHP, etc.). *Ho et al.* (2010) present a study on MCDM applications in supplier selection and evaluation. From 2000 to 2008 they find 78 articles that match their search criteria. *Ho et al.* report that the most applied single MCDM approach in sup-

plier selection is data envelopment analysis (DEA), whereas the most frequently utilized integrated approach is the AHP. Furthermore, they state that all the approaches they review can consider qualitative as well as quantitative criteria.

The high number of reviews on MCDM applications general or not method-specific or about a certain research area, reflects the strong interest of academia in this topic, confirming the relevance of MCDM methods in several research areas. The interest of academia concerning MCDM methods is not surprising from the perspective of modern decision making and management practices. Pure cost minimization – as well as profit maximization – is, in many cases, a strong simplification of the underlying problem. The persistent rejection of shareholder value concepts and the continual increase of sustainability aspects will further influence decision making in the future and lead to an additional relevance increase of MCDM approaches in several management areas. Due to the high applicability of MCDM approaches to different kinds of problems, MCDM approaches are applicable to many decision problems. Generally, MOMP approaches are applied to optimization problems (with some exceptions), non-classical approaches are applied to problems that incorporate high uncertainty, especially uncertainty regarding information quality, and MAUT as well as outranking methods are applied for preference modeling. One of our goals in this paper is to give an overview of MCDM methods and the problems they are applied to in SCM.

3. Multiple criteria decision making in supply chain management

In this paragraph we present the results of our literature review. We start with an introduction to our research approach, followed by a general overview on the development of MCDM applications to SCM. The last subsection reviews the MCDM applications in the various SCM application areas in more detail.

3.1 Methodological approach of the literature survey

Our literature review is restricted to peer reviewed publications. This includes academic journals and conference proceedings, but excludes books, master and doctoral theses. We reviewed articles published in the period from 2000 to 2011. The literature query took place on 30th April 2011. We used the databases EBSCO Host (Business Source Premier, EconLit, Computer Source) and ABI/INFORM Complete (ProQuest). We searched within titles and abstracts. *Table 1* lists the search terms we considered. We used method unspecific as well as method specific MCDM search terms and SCM search terms. The search terms within the columns were linked with each other with the operator "OR", method specific and unspecific search terms (column one and two) were linked with the operator "OR", the SCM search terms (column three) were linked with the operator "AND". Therefore each hit at least included a method specific or unspecific word and "supply chain" or "SCM". The methodological approach of our literature survey is similar to *Glock/Hochrein* (2011) as well as to *Kudla/Stölzle* (2011).

MCDM search terms		MCDM search terms		SCM search terms
method unspecific		method specific		
"multicriteria"		AHP		"supply chain"
"multi criteria"		"analytic hierarchy process"		SCM
"multi attribute"		"analytical hierarchy process"		
"multi attributive"		ANP		
"multiple criteria"		"analytic network process"		
"multiple attribute"		"analytical network process"		
"multiple attributive"	*OR*	ELECTRE	*AND*	
"multiattribute"		fuzzy		
		MACBETH		
		PROMETHEE		
		SMART		
		TOPSIS		
		UTA		

Table 1: Search terms of the literature survey

Since we are especially interested in approaches for the consideration of intangible, qualitative information in MCDM, search terms such as "goal programming" or "mathematical programming" were not included directly in the literature retrieval. However, they also were not excluded, since combinations with qualitative methods and, therefore, consideration of qualitative information are possible in mathematical programming approaches. Overall, 334 papers matched the search terms; 124 were relevant to the topic.

The following three conditions with respect to the retrieved articles were evaluated for the decision whether or not to include an article in the review:

(1) usage of a multiple criteria approach,
(2) consideration of qualitative or intangible information,
(3) clear relation to SCM research.

As described in the introduction, since reviews on purely mathematical decision support are already sufficiently available, we will focus on approaches that allow for the incorporation of qualitative or intangible information. Therefore, mathematical programming approaches that do not consider qualitative or intangible information are excluded from the review. Furthermore, methods that handle pure quantitative problems, which include qualitative information about uncertainties (e.g. fuzzy demand), are not considered (e.g. *Mahnam et al.* 2009). In addition, all non multiple criteria applications of fuzzy set theory are excluded (e.g. *Kabak/Ülengin* 2011). In many cases, weightings of multiple criteria goal programming approaches are generated by means of qualitative evaluation through a decision maker (e.g. *Efendigil et al.* 2008; *Amid et al.* 2011), in some cases, even the weightings are computed through quantitative information within an optimization prob-

lem (e.g. *Chan et al.* 2005; *Chan et al.* 2006). Regarding item (3), several papers were found which use the term "supply chain", since it is a buzzword that increases academic impact. These papers were also excluded. We focus on publications that clearly contribute to SCM relevant research area, e.g. purchasing, distribution or collaboration, which consider inter-organizational aspects.

After eliminating irrelevant contributions, the papers were classified by publication year, journal of publication and whether or not a group decision approach or empirical results are included. Furthermore, we analyzed the MCDM category (MOMP, MAUT etc.), and the exact method (AHP, fuzzy set theory) of the paper. If a contribution uses more than one method, we identified the central method (first stated) and classified the papers considering up to three MCDM categories and methods. Additionally, we surveyed whether the approaches are integrated. In some cases, different methods are used side by side without interacting with each other. These approaches are classified as not integrated. The last attribute we categorized is the application area within SCM. The derivation of the different SCM application areas starts at the strategic decision level of *design*, followed by directly value adding areas, i.e. *purchasing*, *manufacturing*, *distribution* and *logistics*. We then considered supporting areas, i.e. *collaboration* and performance management. However, six publications were not assignable to these application areas and are therefore classified as miscellaneous. Moreover, the reviewed papers in each application area were assigned to the problem they consider (specific application area; e.g. complete network design, distribution network design, etc.).

3.2 General overview of multiple criteria decision making in supply chain management

In this section we present a general review of MCDM in SCM. The analyses focus on giving a compact insight on the development of the appropriate research field.

In *Table 2,* development of MCDM categories in SCM from 2000 to 2011 is depicted. In addition, the lower part of the table describes shares of papers that include integrated approaches, state case applications or group decision approaches. The number of applications has significantly increased in the last six years. In 2008, there is an abrupt rise that is hardly explainable by means of the obtained data in the literature review. One noticeable exception is, in this year eight single contribution journals (published only one article in the regarded research area and time frame) issued an article. However, even if the single contribution journals are neglected for this analysis, there is still a leap. Another peculiarity is the high number of publications in internationally not well recognized journals in 2008. If internationally less recognized journals are neglected for evaluation, there is still a peak, but a less significant one. On the other hand, for 2011, it is expected that the number of MCDM publications in SCM will exceed the number in 2008.

Regarding the method categorization, MAUT applications are clearly dominant, certainly, due to the exclusion of purely quantitative methods. Nevertheless, even if purely quantitative methods would have been considered for the review, we expect that MAUT application would still dominate the picture. Integrated approaches represented the greater part of the approaches already from 2003 to 2005.

Methods	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Total
Total	2	3	3	7	5	7	15	13	25	14	15	15	124
Multi-attributive utility theory	2	3	3	3	4	5	5	11	20	9	12	7	84
Multi-objective mathematical programming				1	1	1	3		1	1	2	2	12
Non-classical				3		1	7	2	4	4	1	5	27
Outranking												1	1
Integrated approaches	0%	33%	33%	57%	60%	57%	47%	62%	48%	79%	67%	67%	57%
Case application	50%	0%	0%	29%	40%	14%	47%	54%	48%	50%	40%	40%	41%
Group decision approaches	50%	33%	0%	0%	20%	14%	7%	23%	8%	21%	7%	13%	13%

Table 2: MCDM categories in SCM per year

Since 2009, integrated approaches constitute the bulk of contributions. Furthermore, we reviewed whether the articles integrated a case application of the proposed methodology to a real life problem. 41% of the papers integrate an actual case study and a further 11% of the articles incorporate a fictive example case (not stated in the table). Additionally, we surveyed the ratio of MCDM applications explicitly allowing for the consideration of more than one decision maker (group decisions). 13% of the reviewed papers represent a group decision methodology.

Table 3 shows MCDM methods applied five or more times in the regarded time frame. The total number of applications exceeds the number of reviewed journals, since a utilization of two or more methods in a publication is considered. The methods AHP, fuzzy set theory and ANP represent 63% of all applications. Furthermore, like *Wallenius et al.* (2008) and *Sipahi/Timor* (2010) report in general, *Table 3* presents for SCM a strong increase in AHP and ANP applications. Additionally, fuzzy set theory applications increased in recent years. In 46 articles one, in 58 articles two and in 20 articles three methods are applied. Occasionally, even four methods are employed. The increase in method applications per year presents the same picture as the number of contributions per year, a strong increase in 2006. However, the number of applications rises after 2006, instead of stagnating like the number of articles published.

Furthermore, the methods to articles ratio (total number of applications per year divided by the total number of contributions per year) in the last row of *Table 3* also indicates increasing application of two or more methods within an application.

Method	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Total
AHP	2	3	1	5	3	5	5	10	19	8	8	6	75
Fuzzy set theory				3	1	1	7	5	9	7	5	10	48
ANP			1	1	1		2	1	2	2	5	2	17
Goal programming				1	2	1	1		2	3	2		12
DEA									1		2	2	5
Integer linear programming		1	1						1	1	1		5
Multi-objective linear programming							2		2		1		5
…	…	…	…	…	…	…	…	…	…	…	…	…	…
Total	2	4	4	11	9	13	24	24	45	28	30	28	222
Methods to article ratio	1.00	1.33	1.33	1.57	1.80	1.86	1.60	1.85	1.80	2.00	2.00	1.87	1.79

Table 3: MCDM methods in SCM per year

Table 4 shows the 13 journals and conference proceedings that published three or more articles in the regarded research area from 2000 to 2011 and the primary MCDM method applied in the contribution. Overall, 49 journals contribute to the regarded research area. Most of the listed journals are internationally well-regarded and highly ranked, in journal rankings like "Association of Business Schools Academic Journal Quality Guide March 2010" and the "Association of Professors of Business in German speaking countries" VHB 2011. The articles in these journals account for 62% of all the contributions in this research field from 2000 to 2011. In the five most publishing journals of MCDM in SCM, the European Journal of Operational Research (EJOR), International Journal of Production Economics (IJPE), and International Journal of Production Research (IJPR) are known for their stronger connection to operations research topics. If purely quantitative approaches would have been considered, too, it is assumed that EJOR would have been positioned at the third place or even higher. The contributions within the journals EJOR, IJPE, and IJPR correspond closely to their reputation. Thus, the focus lies on methodological aspects. Regarding the dominant methods in the top 2 journals, IJPE and IJPR, it is evident that, besides MAUT methods, IJPE mostly publishes mainly non-classical approaches. Therefore, IJPE mainly contributes to research streams that consider imprecise and incomplete information, like most non-classical MCDM methods do. On the other side, IJPR focuses on mathematical programming MCDM methods, which primarily treat optimization problems. The contributions in the journals Production Planning & Control and Supply Chain Management: An International Journal, are more concerned with content-related aspects.

	Journal or conference proceeding	MAUT	MOMP	Non-classical	Outranking	Total
1	International Journal of Production Economics	11	1	6		18
2	International Journal of Production Research	8	5		1	14
3	Production Planning & Control	7		1		8
4	Supply Chain Management: An International Journal	5	1			6
5	European Journal of Operational Research	3		2		5
6	International Journal of Management & Decision Making	4				4
7	Benchmarking: An International Journal	3		1		4
8	Computers & Industrial Engineering	3				3
9	Computers in Industry	2		1		3
10	IIE Annual Conference. Proceedings	2	1			3
11	International Journal of Physical Distribution & Logistics Management	2		1		3
12	Journal of Cleaner Production	1	1	1		3
13	Journal of the Operational Research Society	1	1	1		3

Table 4: Top 13 journals and conference proceedings

The rows in *Table 5* present the predominant method category as well as the exact method. The columns show the second method category in combined approaches and the exact method. The category "no MCDM" incorporates approaches like sensitivity analysis or balanced score card. Applications of three or more methods in one article are not considered in this analysis. The proportion of non-single approaches in this table is higher than the proportion of integrated approaches. In some cases, different single approaches are applied besides each other, but do not interact and are not integrated. As apparent, AHP and ANP applications are the dominant methods within the reviewed articles, followed by fuzzy set theory and goal programming approaches. With respect to combined approaches, joint AHP and fuzzy set theory approaches are clearly dominant. These two methods also represent the approaches most often combined with other methods. The second ranked combination is AHP and goal programming, the top three method combination AHP and integer linear programming.

	MAUT						MOMP							Non-classical				Out-ranking		Others		No MCDM									Single approaches	Total
	AHP	ANP	MACBETH	SMART	TOPSIS	Weighted average method	DEA	Dynamic programming	Goal programming	Integer linear programming	Linear programming	Multiple-objective integer linear programming	Multi-objective linear programming	Choquet integrals	Fuzzy set theory	Genetic algorithm	Grey relational analysis	ELECTRE	PROMETHEE	Entropy weight	QFD	Bi-negotiation agents	BSC	Interpretive structural modelling	Neural networks	Performance value analysis	Sensitivity analysis	Simulation	System dynamics	Taguchi loss function	Single approaches	
MAUT																																
AHP				1			1	1	6	4	1				18	1	1	1			1	1	2	1	1	1	1	1	1	1	21	
ANP									1	1			1	1	2																9	
MAUT															1																2	
SMART																															1	
TOPSIS															1																	
Voting AHP																															1	
MOMP																																
DEA		1			1														1													3
Goal programming	1	1													2																	4
Linear programming															1																	1
Multi-objective integer linear optimization	1																															1
Multi-objective linear programming															2																2	4
Non-classical																																
Choquet integral			1												1																	2
Fuzzy set theory	3				1	1						1									1										10	17
Genetic algorithm	1														1																	2
Grey relational analysis	1																															1
Outranking																																
ELECTRE																				1												1
Total	7	2	1	1	2	1	1	1	7	2	1	3	2	1	29	1	1	1	1	1	2	1	2	1	1	1	1	1	1	1	46	124

Table 5: MCDM method combinations in SCM

Table 6 represents the number of applications to different application areas in SCM and the table lists the articles published in this area. The application areas map important functions in SCM based on the value adding process and supporting activities, as long as MCDM methods have been applied to this functions. The purchasing area is the most frequented area, followed by logistics and performance management.

Application area	Papers	Total number
Design	[3], [10], [36], [43], [50], [53], [72], [76], [88], [96], [104]	11
Purchasing	[4], [5], [14], [16], [18], [19], [20], [23], [25], [27], [28], [30], [31], [40], [51], [55], [56], [57], [58], [60], [63], [64], [65], [66], [67], [70], [71], [73], [74], [75], [78], [81], [82], [83], [84], [85], [86], [87], [93], [95], [98], [100], [101], [103], [110], [111], [112], [115], [116], [117], [119], [120], [121], [123]	54
Manufacturing	[6], [7], [33], [54], [77], [90], [91], [102], [109]	9
Distribution	[22], [68]	2
Collaboration	[8], [9], [26], [35], [46], [69], [79], [80], [89], [107]	10
Logistics	[15], [17], [29], [32], [34], [37], [41], [42], [47], [48], [49], [52], [59], [62], [94], [106], [114], [122]	18
Performance management	[1], [2], [11], [12], [13], [21], [24], [38], [44], [45], [99], [105], [108], [113]	14
Miscellaneous	[39], [61], [92], [97], [118], [124]	6
Total		124

Table 6: Application areas of MCDM in SCM

The next subsection presents a more detailed description of applications of MCDM methods to the different SCM application areas.

3.3 Review of multiple criteria decision making with respect to application areas in supply chain management

In this section, we provide a detailed analysis of selected papers within each SCM application area. At the beginning of each subsection, we present a table giving an overview of the relevant SCM application area.

3.3.1 Design

Table 7 represents the application area "design" summary. Within each specific application area, there is no clear focus. Complete networks, as well as distribution and manufacturing networks, are also considered. The reviewed papers considered only supply networks in holistic approaches (complete networks); supply networks are not listed in *Table* 7. The most applied method combination, AHP and integer linear programming occurs due to the frequent optimization problems in this area. In comparison with other applica-

tion areas, the AHP method takes a dominant position within the design area only comparable to the purchasing area. The share of integrated approaches and papers with case studies differ only slightly from the averages of the whole population. The journal with the highest number of contributions from 2000 to 2011 is the International Journal of Management & Decision Making (2 / 11).

Specific application area	Paper count	Most applied method or method combination	Share of integrated approaches	Case studies (share of total no.)
Distribution network	3	AHP	67%	67%
Complete network	3	AHP	67%	0%
Manufacturing network	3	AHP	0%	33%
Reverse logistics network design	2	AHP	100%	100%
Total	11	AHP	55%	45%

Table 7: Overview SCM application area "design"

3.3.2 Purchasing

Table 8 represents the summary of the application area "purchasing". In the application area purchasing, supplier selection is the predominant specific application area with 44 of 54 papers devoted to this topic. The prevalent method and method combination do not deviate significantly from the population although AHP plays a key role. However, the share of integrated approaches (67%) is significantly higher compared to the population (57%). This indicates, that approaches within this application area are more sophisticated than the average approach in the population. The most frequently contributing journals in purchasing are the International Journal of Production Economics (9 / 54) and the International Journal of Production Research (9 / 54).

Specific application area	Paper count	Most applied method or method combination	Share of integrated approaches	Case studies (share of total no.)
Supplier selection	44	AHP & Fuzzy set theory	70%	36%
Supplier evaluation	6	AHP	33%	17%
Software selection	2	AHP	100%	50%
Supplier risk assessment	2	AHP	50%	50%
Total	54	AHP, AHP & Fuzzy set theory	67%	35%

Table 8: Overview SCM application area "purchasing"

3.3.3 Manufacturing

Table 9 represents the summary of the application area "manufacturing". Regarding the specific application area in manufacturing, the focus of MCDM applications is in outsourcing and production planning. The two main methods are AHP and Goal programming. The latter is an indicator for a high number of optimizations concerning production planning. A very mixed application of methods is quite striking within the manufacturing area. The share of integrated approaches is significantly lower and the share of papers with case studies is noticeably higher than in the population. The journals with the highest number of contributions are again the International Journal of Production Economics (2 / 9) and International Journal of Production Research (2 / 9).

Specific application area	Paper count	Most applied method or method combination	Share of integrated approaches	Case studies (share of total no.)
Outsourcing	3	Goal programming & ANP, Smart	33%	33%
Production planning	3	AHP, ANP, Goal Programming	33%	100%
Collaborative production planning	1	Multi-objective linear programming	0%	0%
Service and manufacturing optimization	1	AHP & System dynamics	100%	0%
Sustainability	1	Fuzzy set theory	0%	100%
Total	9	AHP, Goal programming	33%	56%

Table 9: Overview SCM application area "manufacturing"

3.3.4 Distribution

Table 10 represents the summary of the application area "distribution". Only two contributions of all 124 reviewed articles concern distribution problems. Both consider distribution planning problems. Certainly, more MCDM applications may be found in this area. However, they are often purely quantitative and therefore not considered in this review. Both articles chosen reveal a different methodological approach. Among journals contributing to this area, the International Journal of Computer Integrated Manufacturing and the International Journal of Production Research published each one article in this SCM application area.

Specific application area	Paper count	Most applied method or method combination	Share of integrated approaches	Case studies (share of total no.)
Distribution planning	2	Multi-objective linear programming & Fuzzy set theory, AHP & Genetic algorithm	50%	50%
Total	2	Multi-objective linear programming & Fuzzy set theory, AHP & Genetic algorithm	50%	50%

Table 10: Overview SCM application area "distribution"

3.3.5 Collaboration

Table 11 presents the summary of the application area "collaboration". Besides information sharing, horizontal collaboration between supply chains is the specific application area with the highest number of contributions. Since collaboration is a rather soft and intangible application area, AHP as well as AHP in combination with fuzzy set theory emerge unsurprisingly as the most applied method. Again, the share of integrated papers incorporating case studies does not significantly deviate from the population, although it is slightly higher in both categories. The journals with the highest number of contributions in this area are the International Journal of Production Economics (2 / 10) and Production Planning & Control (2 / 10).

Specific application area	Paper count	Most applied method or method combination	Share of integrated approaches	Case studies (share of total no.)
Information sharing	4	AHP & Fuzzy set theory	100%	25%
Horizontal collaboration	3	AHP	33%	67%
Agile partnerships	1	Fuzzy set theory	0%	100%
Integration	1	Fuzzy set theory	0%	100%
Process transformation	1	AHP & QFD	100%	100%
Total	10	AHP, AHP & Fuzzy set theory	60%	60%

Table 11: Overview SCM application area "collaboration"

3.3.6 Logistics

Table 12 represents the application area "logistics" summary. Like in the purchasing area, in the application area logistics, partner selection in form of 3PRLP (third party reverse logistics provider) and 3PL selection are dominating the field. The selection of partners is of-

ten strongly dependent on intangible, qualitative criteria. Therefore, the most applied method (combination) AHP as well as integrated AHP and fuzzy set theory approaches do not surprise. However, the share of integrated approaches and the share of papers including case studies are significantly lower than in the population. The International Journal of Production Economics (3 / 18) has the highest number of contributions in the area of logistics.

Specific application area	Paper count	Most applied method or method combination	Share of integrated approaches	Case studies (share of total no.)
3PRLP selection	6	AHP & Fuzzy set theory	67%	17%
3PL selection	5	AHP	20%	40%
Agile SC	2	ANP, Fuzzy set theory	0%	50%
4PL evaluation	1	Choquet integral	100%	0%
Customer service management	1	Fuzzy set theory	100%	100%
SC effectiveness	1	ANP	0%	100%
Selection of global logistics strategy	1	AHP & Fuzzy set theory	100%	100%
Supply chain development	1	AHP	0%	0%
Total	18	AHP, AHP & Fuzzy set theory	44%	39%

Table 12: Overview SCM application area "logistics"

3.3.7 Performance management

Table 13 presents the summary of the application area "performance management". In this application area, most contributions have no special focus and consider supply chain performance management generally. Hence, the methods applied set out a heterogeneous picture. As far as the share of integrated approaches and papers including case studies, no

Specific application area	Paper count	Most applied method or method combination	Share of integrated approaches	Case studies (share of total no.)
No special focus	9	AHP, AHP & BSC	67%	33%
Sustainability	3	MAUT	33%	33%
Benchmarking of SCs	1	DEA & PROMETHEE	100%	100%
Reverse logistics	1	AHP & DEA	100%	100%
Total	14	AHP, AHP & BSC	64%	43%

Table 13: Overview SCM application area "performance management"

significant deviations from the population are apparent: both stay slightly above average. The most contributing journals in this area are Production Planning & Control (2 / 14) and Supply Chain Management: An International Journal (2 / 14).

3.3.8 Miscellaneous

Table 14 presents the summary of MCDM applications not assignable to other application areas. The papers subsumed under 'miscellaneous' either do not represent a typical task in SCM, or are numbered too low to build an application area of their own in this literature survey. A general description is not very meaningful, since the problems presented differ strongly from each other. The AHP method is clearly dominant.

	Paper count	Most applied method or method combination	Share of integrated approaches	Case studies (share of total no.)
Project selection	3	ANP	33%	0%
Risk management	1	AHP	0%	100%
SC competitiveness positioning in shipbuilding	1	AHP & Fuzzy set theory	100%	0%
SC quality management	1	AHP	0%	100%
Total	6	AHP	33%	33%

Table 14: Overview SCM application area "miscellaneous"

4. Discussion

In this section we will discuss limitations of our literature study, summarize the findings of the earlier sections and derive possible trends of MCDM applications in SCM.

Regarding limitations of our literature survey, the review was restricted to academic peer-reviewed articles. Textbooks, master theses and doctoral dissertations were thus not selected; furthermore, only articles in English were considered. Additionally, our literature study of MCDM methods is restricted to approaches applied in a SCM context. Therefore, applications used in distribution, manufacturing or purchasing without SCM connection have not been examined in our study. Moreover, our investigation is based on a keyword search in the databases EBSCO Host (Business Source Premier, EconLit, Computer Source) and ABI/INFORM Complete (ProQuest). Hence, it is possible that some relevant articles did not match our search terms or were not listed in the searched databases. However, we are quite confident about the thoroughness of our study. Finally, we scrutinized only methods that explicitly allow for the consideration of qualitative or intangible information within the decision process. Therefore, purely quantitative methods, as well as methods using only qualitative information for the estimation of uncertainties for an input variable (e.g. fuzzy demand) are excluded.

For the derivation of future trends of MCDM in SCM, two triggers can be distinguished:

a) current and future developments in SCM research offer new application areas or require the consideration of criteria not yet considered, and
b) evolution of MCDM methods may offer new application opportunities in SCM.

The methodological proceeding for the derivation of research gaps and future trends follow; first, we evaluated the results of our literature analysis and deduced research gaps. Independent from future developments in SCM or MCDM, these gaps need to be closed and require further academic attention. Second, we considered future developments in SCM and resulting new application areas or areas which may experience a strong shift in its needs, or criteria that must be considered. This investigation yields possible future trends of MCDM in SCM arising from alterations in SCM research. Third, we regarded new MCDM methods which may be useful to SCM research.

In the following we will briefly analyze which future trends of MCDM applications in SCM may emerge from these two triggers, considering the results from the literature review.

4.1 Current state and future developments in SCM research

After considering current and future developments in SCM, we first summarize our findings from the previous section and show research gaps in current and future SCM research. We support and augment our line of argument through a literature review of current SCM research (*Giunipero et al.* 2008) and a Delphi study on future SCM trends (*Melnyk et al.* 2009).

The general overview of MCDM methods in SCM shows that this research field is rapidly growing. In 2011 we expect about 30 publications on MCDM in SCM; 15 articles will already be available by the end of April exceeding the highest number in 2008 (25 publications). Furthermore, we assume that the trend toward combining methods will increase, especially among approaches that combine readily with others. As far as results from the literature review, this applies particularly to AHP, ANP and fuzzy set theory.

As for methodological tendencies of individual application areas, it is no surprise that with logistics' particular focus on optimization, purchasing focuses more on methods allowing for the consideration of qualitative and imprecise information. The share of integrated approaches is an indicator of the approaches' sophistication and varies between the application areas. Purchasing is the most highly developed application area when ranked by number of publications and share of integrated approaches. In contrast, the application area distribution is largely ignored by academia. Overall, only five contributions are concerned with distribution (counting three papers on distribution network design, assigned to the application area design). This is surprising, since combinations of MOMP and MAUT or outranking approaches may offer significant advantages over purely quantitative approaches in this area. However, most of the specific application areas and problems are not surveyed in great detail. Only topics like supplier selection and evaluation, 3PL and 3PRLP selection – and general performance management – are surveyed by high numbers of contributions. Particularly surprising is the lack of papers on risk management. Overall, there are only three articles, two on supplier and one on general risk management. Risks are hard to identify and even harder to quantify. Therefore, AHP, ANP and

fuzzy set theory approaches are expected to offer great potential for application in this area.

To support and complement our argument, we use results from the most recent and comprehensive SCM literature review available. *Giunipero et al.* (2008) survey 405 articles from nine SCM peer-reviewed journals. However, their evaluation of future developments in SCM research focuses on research methods that have to be employed to advance the state of knowledge in SCM. Therefore, we refer to *Melnyk et al.* (2009) on future trends in SCM research. Based on a literature review, they conduct a Delphi study, integrating academics as well as practitioners. Appropriate practitioners are identified using the AMR research list of the top 25 supply chain firms; academics are selected from North American universities with a good reputation in SCM.

Giunipero et al. (2008) state that the most frequented SCM research area is SCM strategy. They describe it as "strategic alignment between the supply chain and the focal firm", and refer to content like competitive advantage and risk management. Risk management was already identified as an underrepresented area. *Melnyk et al.* (2009) report "supply chain disruption risk" as the single most important area with respect to future SCM. Therefore, further MCDM approaches for risk management, focused on the supply side or not, would be helpful for SCM research.

Aligning various supply chain strategy areas within the supply chain as well as competitive positioning (advantage) are completely neglected by MCDM research. The importance of this area is also stated by *Melnyk et al.* (2009). They find that SCM is still mainly concerned with efficiency related topics (e.g. cost minimization), but that effectiveness will increasingly become the focus of SCM and strategy related issues. For example, selection of an inter-organizational supply chain strategy, including a group decision-making approach might be a possible application area for MCDM. Furthermore, the developing trend of supply chain differentiation (cf. *Hilletofth* 2009) will increase the importance of topics like supply chain strategy and competitive positioning. Supply chain differentiation concerns the concurrent operation of several parallel supply chains, effectively and efficiently satisfying customer needs. Firms like AT Kearney (*Mayer et al.* 2009), McKinsey & Company (*Malik et al.* 2011) and Gartner (*Davis* 2010) report how this strong trend finds it way into SCM. Issues that might arise here include the right (optimal) number of supply chains a company should operate. One paper in the review examines competitive positioning in the shipbuilding industry (*Zangoueinezhad et al.* 2011). Supply chain strategy, including topics like supply chain differentiation, alignment of supply chain strategy and competitive positioning, represents an application area for further MCDM approaches.

Supply chain performance management is an application area currently given "average" attention (14 papers). Certainly, at first glance, one would deduce that this area is well covered and offers – per se – potential for further MCDM applications. However, the trend of supply chain differentiation will demand new performance management systems. *Agarwal et al.* (2006) offer a first suggestion how such performance management systems might be built. However, this approach would have to be adapted to the needs of a differentiated supply chain. Performance management presents an area where further MCDM approaches might be needed.

In summary our analysis revealed two research gaps in MCDM applications in SCM requiring further consideration:

i. Distribution in a supply chain context, including distribution network design as well as (collaborative) distribution planning, and
ii. Supply chain risk management, including a pure focus on the supply side and consideration of the whole supply chain (end-to-end).

Furthermore, present trends in SCM research may initiate a need for new MCDM applications in these areas:

iii. Supply chain strategy, including supply chain differentiation, competitive positioning and alignment of supply chain strategy, and
iv. Supply chain performance management, especially for the performance management of several parallel supply chains.

4.2 Evolution of MCDM methods

As described in section 2.1, research on MCDM is growing rapidly; new methods and innovative applications of existing methods are common. In this paragraph, we will discuss which new SCM applications could be offered by future MCDM developments. We support our argument using a meta review of developments in MCDM (*Wallenius et al.* 2008).

Mental models, sometimes also referred to as decision maps, offer good prospects for further MCDM research (cf. *Wallenius et al.* 2008; *Comes et al.* 2011). Mental models attempt to measure the perception of a decision maker and how different attributes of a solution alternative may affect an objective. The model estimates how attributes of different solution alternatives might impact specific consequences related to value concepts. Mental models may introduce a new era in decision making in SCM. Where current decisions are formulated solely to a specific problem, mental models focus on the effect of the selected solution on a higher objective level. For example, current decision problems with supply chain network design focus, in most cases, on cost minimization. A mental model would be formulated considering a higher objective level, e.g. maximize the possible achievable customer satisfaction while holding costs at a reasonable level. Supplier selection problems might not be formulated as "which supplier meets our requirements" but as "which supplier has the most positive impact on the overall quality and on revenues as well as profit." An example for such a model is *Montibeller et al.* (2008). These approaches are very general and are therefore applicable to a wide range of decision problems. We expect that we will see first applications of mental SCM models in the near future.

A further recent research area in MCDM is revisiting targets, which is especially suitable for decision problems concerning achievement of a specific target value (cf. *Tsetlin/Winter* 2007; *Wallenius et al.* 2008). Such approaches are especially interesting for supplier selection. Certain criteria may be interpreted as qualifying criteria and therefore represent a binary criteria (possible values 1 and 0), where the supplier is evaluated with a 1 if he satisfies the criteria and a 0 if he does not. Combined with other criteria, which measure the actual goal attainment, this might be a worthwhile approach and could also function for other areas like supply chain design: i.e. does a location match certain binary criteria, or how high is the goal attainment of other criteria. Revisiting targets are implementable in currently existing approaches and thereby represent a methodological advancement. Also in this area, first implementations in SCM can be expected soon.

Wallenius et al. (2008) state that due to the progress made in computer design with respect to computing power, optimization problems with high computational requirements will be an interesting MCDM research area. Quadratic and stochastic programming are such areas. In this optimization class, one or two objective functions may be quadratic and quadratic objective functions may also represent variance and thus uncertainty. Such problems are not computable yet, but will be in the near future (cf. *Ehrgott et al.* 2009). Like revisiting targets, this trend represents a methodological advancement. However, it is only implementable in MOMP approaches and therefore not as broadly applicable as revisiting targets; it might only be utilized in SCM application areas where optimization approaches are common. These application areas include supply chain design, distribution and manufacturing planning. Nevertheless, this further development of optimization approaches might be useful for these application areas.

Further mathematical developments with good prospects in MCDM research are evolutionary multi objective optimization approaches, which are search algorithms (heuristics) that basically imitate natural evolution (cf. *Wallenius et al.* 2008; *Rachmawati/Srinivasan* 2010). Genetic algorithms are a very common approach in this area. Three articles on genetic algorithms have been considered in our study. *Chan/Chung* (2004) regard distribution planning problem, *Ohdar/Ray* (2004) present an approach for supplier evaluation in the application area purchasing, and *Sha/Che* (2006) introduce a procedure for supply chain design of a complete network. Since genetic algorithms are heuristics for quantitative problems, they are especially suitable for the application areas of supply chain design, distribution and manufacturing planning, like quadratic and stochastic programming.

To summarize: in MCDM research advancements, we expect significant impact on MCDM approaches in SCM, especially from two areas:

i. Mental models and
ii. Revisiting targets.

Due to their wide adaptability, these MCDM research areas offer high potential for application to SCM research. Certainly, quadratic and stochastic programming, as well as evolutionary multi objective optimization, will be utilized in SCM. However, mental models and revisiting targets, particularly in combination with other MCDM methods, offer higher potential for application in SCM and better opportunities for initiating MCDM research trends in SCM.

5. Conclusion

This paper is a literature survey on MCDM applications in SCM. MCDM and SCM are both rapidly growing research fields. However, a structured analysis with respect to MCDM approaches in SCM is not yet available. We focused on approaches allowing for the consideration of qualitative information. Overall, 334 articles matched our search criteria in the time frame from 2000 to 2011. We categorized these papers according to the year and publishing journal, analyzed SCM application areas, classified the MCDM methods and studied whether two or more methods were combined, group decision procedure was incorporated, or if a case study application provided support. The main conclusion of our analysis is: publications on MCDM in SCM are rapidly growing, especially combined approaches. Based on our findings, we suggest further research, especially in the application areas of distribution in SCM context, supply chain risk management, strategy and

performance management. Looking to the future of MCDM research, we expect that mental models and revisiting targets have the potential for establishing a new trend of MCDM applications in SCM. For business practice as well as for academia, this article offers a valuable overview regarding MCDM methods for SCM decision problems.

References

Agarwal, A., et al. (2006): Modeling the metrics of lean, agile and leagile supply chain: An ANP-based approach, in: European Journal of Operational Research, Vol. 173, No. 1, pp. 211-225.

Amid, A., et al. (2011): A weighted max-min model for fuzzy multi-objective supplier selection in a supply chain, in: International Journal of Production Economics, Vol. 131, No. 1, pp. 139-145.

Axsäter, S. (2006): Inventory control, Boston, MA.

Behzadian, M., et al. (2010): PROMETHEE: A comprehensive literature review on methodologies and applications, in: European Journal of Operational Research, Vol. 200, No. 1, pp. 198-215.

Bragge, J., et al. (2010): Bibliometric analysis of multiple criteria decision making/multiattribute utility theory, in: Multiple criteria decision making for sustainable energy and transportation systems, pp. 259-268.

Brans, J.P./Vincke, P. (1985): A preference ranking organisation method, in: Management Science, Vol. 31, No. 6, pp. 647-656.

Büyüközkan, G., et al. (2009): Evaluation of 4PL operating models: A decision making approach based on 2-additive Choquet integral, in: International Journal of Production Economics, Vol. 121, No. 1, pp. 112-120.

Chan, F.T.S./Chung, S.H. (2004): A multi-criterion genetic algorithm for order distribution in a demand driven supply chain, in: International Journal of Computer Integrated Manufacturing, Vol. 17, No. 4, pp. 339-351.

Chan, F.T.S., et al. (2005): A hybrid genetic algorithm for production and distribution, in: Omega, Vol. 33, No. 4, pp. 345-355.

Chan, F.T., et al. (2006): Optimization of order fulfillment in distribution network problems, in: Journal of Intelligent Manufacturing, Vol. 17, No. 3, pp. 307-319.

Charnes, A./Cooper, W.W. (1961): Management models and industrial applications of linear programming, New York.

Churchman, C.W./Ackoff, R.L. (1954): An approximate measure of value, in: Operations Research, Vol. 2, No. 2, pp. 172-187.

Comes, T., et al. (2011): Decision maps: A framework for multi-criteria decision support under severe uncertainty, in: Decision Support Systems, Vol. 52, No. 1, pp. 108-118.

Davis, M. (2010): Case study for supply chain leaders: Dell's transformative journey through supply chain segmentation.

Dyer, J.S. (2005): MAUT – Multiattribute utility theory, in: *Figueira, J., et al.* (eds.): International Series in Operations Research & Management Science, New York, pp. 265-296.

Dyer, J.S., et al. (1992): Multiple criteria decision making, multiattribute utility theory: the next ten years, in: Management Science, Vol. 38, No. 5, pp. 645-654.

Efendigil, T., et al. (2008): A holistic approach for selecting a third-party reverse logistics provider in the presence of vagueness, in: Computers & Industrial Engineering, Vol. 54, No. 2, pp. 269-287.

Ehrgott, M., et al. (2009): Multiobjective Programming and Multiattribute Utility Functions in Portfolio Optimization, in: INFOR, Vol. 47, No. 1, pp. 31-42.

Ehrgott, M./Wiecek, M.M. (2005): Multiobjective programming, in: *Figueira, J., et al.* (eds.): International Series in Operations Research & Management Science, New York, pp. 667-722.

Figueira, J., et al. (2005): Multiple criteria decision analysis: State of the art surveys, in: *Figueira, J., et al.* International Series in Operations Research & Management Science, New York, NY.

Giunipero, L.C., et al. (2008): A decade of SCM literature: past, present and future implications, in: Journal of Supply Chain Management, Vol. 44, No. 4, pp. 66-86.

Glock, C.H./Hochrein, S. (2011): Purchasing Organization and Design: A Literature Review, in: BuR – Business Research, Vol. 4, No. 2, pp. 149-191.

Godsell, J., et al. (2011): Enabling supply chain segmentation through demand profiling, in: International Journal of Physical Distribution & Logistics Management, Vol. 41, No. 3, pp. 296-314.

Ha, A.Y./Tong, S. (2008): Contracting and information sharing under supply chain competition, in: Management Science, Vol. 54, No. 4, pp. 701-715.

Hilletofth, P. (2009): How to develop a differentiated supply chain strategy, in: Industrial Management & Data Systems, Vol. 109, No. 1, pp. 16-33.

Ho, W. (2008): Integrated analytic hierarchy process and its applications – A literature review, in: European Journal of Operational Research, Vol. 186, No. 1, pp. 211-228.

Ho, W., et al. (2010): Multi-criteria decision making approaches for supplier evaluation and selection: A literature review, in: European Journal of Operational Research, Vol. 202, No. 1, pp. 16-24.

Hofmann, E. (2010): Linking corporate strategy and supply chain management, in: International Journal of Physical Distribution & Logistics Management, Vol. 40, No. 4, pp. 256-276.

Jain, V., et al. (2009): Select supplier-related issues in modelling a dynamic supply chain: potential, challenges and direction for future research, in: International Journal of Production Research, Vol. 47, No. 11, pp. 3013-3039.

Kabak, Z./Ülengin, F. (2011): Possibilistic linear-programming approach for supply chain networking decisions, in: European Journal of Operational Research, Vol. 209, No. 3, pp. 253-264.

Kudla, N./Stölzle, W. (2011): Sustainability Supply Chain Management Research: A structured Literature Review, in: Die Unternehmung - Swiss Journal of Business Research and Practice, No. 3, pp. 261-300.

Li, L. (2002): Information sharing in a supply chain with horizontal competition, in: Management Science, Vol. 48, No. 9, pp. 1196-1212.

Liberatore, M.J./Nydick, R.L. (2008): The analytic hierarchy process in medical and health care decision making: A literature review, in: European Journal of Operational Research, Vol. 189, No. 1, pp. 194-207.

Mahnam, M., et al. (2009): Supply chain modeling in uncertain environment with bi-objective approach, in: Computers & Industrial Engineering, Vol. 56, No. 4, pp. 1535-1544.

Malik, Y., et al. (2011): Building the supply chain of the future, in: McKinsey Quarterly, No. 1, pp. 62-71.

Mayer, S., et al. (2009): 6th European A.T. Kearney/ELA Logistics Study 2008/2009. Supply chain excellence amidst the global economic crisis.

Meixell, M.J./Gargeya, V.B. (2005): Global supply chain design: a literature review and critique, in: Transportation Research: Part E: Logistics and Transportation Review, Vol. 41, No. 6, pp. 531-550.

Melnyk, S.A., et al. (2009): Mapping the future of supply chain management: a Delphi study, in: International Journal of Production Research, Vol. 47, No. 16, pp. 4629-4653.

Melo, M.T., et al. (2009): Facility location and supply chain management – A review, in: European Journal of Operational Research, Vol. 196, No. 2, pp. 401-412.

Montibeller, G., et al. (2008): Reasoning maps for decision aid: an integrated approach for problem-structuring and multi-criteria evaluation, in: Journal of the Operational Research Society, Vol. 59, No. 5, pp. 575-589.

Montibeller, G./Franco, L.A. (2011): Raising the bar: strategic multi-criteria decision analysis, in: Journal of the Operational Research Society, Vol. 62, No. 5, pp. 855-867.

Mula, J., et al. (2010): Mathematical programming models for supply chain production and transport planning, in: European Journal of Operational Research, Vol. 204, No. 3, pp. 377-390.

Ohdar, R./Ray, P.K. (2004): Performance measurement and evaluation of suppliers in supply chain: An evolutionary fuzzy-based approach, in: Journal of Manufacturing Technology Management, Vol. 15, No. 8, pp. 723-734.

Rachmawati, L./Srinivasan, D. (2010): Incorporation of Imprecise Goal Vectors into Evolutionary Multi-Objective OptimizationIEEE Congress on Evolutionary Computation, 345 E 47TH ST, NEW YORK, NY 10017 USA.

Ram, C., et al. (2011): Extending the use of scenario planning and MCDA for the evaluation of strategic options, in: Journal of the Operational Research Society, Vol. 62, No. 5, pp. 817-829.

Roy, B. (1991): The outranking approach and the foundations of electre methods, in: Theory and Decision, Vol. 31, No. 1, pp. 49-73.

Saaty, T.L./Vargas, L.G. (2006): Decision making with the analytic network process. Economic, political, social and technological applications with benefits, opportunities, costs and risks, Boston, MA.

Sha, D.Y./Che, Z.H. (2006): Supply chain network design: partner selection and production/distribution planning using a systematic model, in: Journal of the Operational Research Society, Vol. 57, No. 1, pp. 52-62.

Sipahi, S./Timor, M. (2010): The analytic hierarchy process and analytic network process: an overview of applications, in: Management Decision, Vol. 48, No. 5, pp. 775-808.

Steuer, R.E./Na, P. (2003): Multiple criteria decision making combined with finance: A categorized bibliographic study, in: European Journal of Operational Research, Vol. 150, No. 3, pp. 496.

Tamiz, M., et al. (1998): Goal programming for decision making: An overview of the current state-of-the-art, in: European Journal of Operational Research, Vol. 111, No. 3, pp. 569-581.

Tsetlin, I./Winkler, R.L. (2007): Decision Making with Multiattribute Performance Targets: The Impact of Changes in Performance and Target Distributions, in: Operations Research, Vol. 55, No. 2, pp. 226-233.

Vaidya, O.S./Kumar, S. (2006): Analytic hierarchy process: An overview of applications, in: European Journal of Operational Research, Vol. 169, No. 1, pp. 1-29.

Vargas, L.G. (1990): An overview of the analytic hierarchy process and its applications, in: European Journal of Operational Research, Vol. 48, No. 1, pp. 2-8.

Wallenius, J., et al. (2008): Multiple criteria decision making, multiattribute utility theory: Recent accomplishments and what lies ahead, in: Management Science, Vol. 54, No. 7, pp. 1336-1349.

Wu, D.D., et al. (2010): Fuzzy multi-objective programming for supplier selection and risk modeling: A possibility approach, in: European Journal of Operational Research, Vol. 200, No. 3, pp. 774-787.

Zangoueinezhad, A., et al. (2011): Using SCOR model with fuzzy MCDM approach to assess competitiveness positioning of supply chains: focus on shipbuilding supply chains, in: Maritime Policy & Management, Vol. 38, No. 1, pp. 93-109.

Zokaei, K./Hines, P. (2007): Achieving consumer focus in supply chains, in: International Journal of Physical Distribution & Logistics Management, Vol. 37, No. 3, pp. 223-247.

Zopounidis, C./Doumpos, M. (2002): Multicriteria classification and sorting methods: A literature review, in: European Journal of Operational Research, Vol. 138, No. 2, pp. 229-246.

Surveyed literature

(1) *Agarwal, A./Shankar, R.* (2002): Analyzing alternatives for improvement in supply chain performance, in: Work Study, Vol. 51, No. 1, pp. 32-37.

(2) *Agarwal, A., et al.* (2006): Modeling the metrics of lean, agile and leagile supply chain: An ANP-based approach, in: European Journal of Operational Research, Vol. 173, No. 1, pp. 211-225.

(3) *Alberto, P.* (2000): The logistics of industrial location decisions: An application of the analytic hierarchy process methodology, in: International Journal of Logistics: Research & Applications, Vol. 3, No. 3, pp. 273-289.

(4) *Amid, A., et al.* (2006): Fuzzy multiobjective linear model for supplier selection in a supply chain, in: International Journal of Production Economics, Vol. 104, No. 2, pp. 394-407.

(5) *Amid, A., et al.* (2011): A weighted max-min model for fuzzy multi-objective supplier selection in a supply chain, in: International Journal of Production Economics, Vol. 131, No. 1, pp. 139-145.

(6) *Arisoy, O./Bidanda, B.* (2006): Multi-expert multi-criteria decision making in outsourcing, in: IIE Annual Conference. Proceedings, pp. 1-7.

(7) *Aviso, K.B., et al.* (2011): Fuzzy input-output model for optimizing eco-industrial supply chains under water footprint constraints, in: Journal of Cleaner Production, Vol. 19, No. 2/3, pp. 187-196.

(8) *Bahinipati, B.K., et al.* (2009): Horizontal collaboration in semiconductor manufacturing industry supply chain: An evaluation of collaboration intensity index, in: Computers & Industrial Engineering, Vol. 57, No. 3, pp. 880-895.

(9) *Baramichai, M., et al.* (2007): Agile supply chain transformation matrix: an integrated tool for creating an agile enterprise, in: Supply Chain Management: An International Journal, Vol. 12, No. 5, pp. 334-348.

(10) *Barker, T./Zabinsky, Z.* (2011): A multicriteria decision making model for reverse logistics using analytical hierarchy process, in: Omega, Vol. 39, No. 5, pp. 558-573.

(11) *Berrah, L./Clivillé, V.* (2007): Towards an aggregation performance measurement system model in a supply chain context, in: Computers in Industry, Vol. 58, No. 7, pp. 709-719.

(12) *Bhagwat, R./Sharma, M.K.* (2007): Performance measurement of supply chain management using the analytical hierarchy process, in: Production Planning & Control, Vol. 18, No. 8, pp. 666-680.

(13) *Bhagwat, R./Sharma, M.K.* (2009): An application of the integrated AHP-PGP model for performance measurement of supply chain management, in: Production Planning & Control, Vol. 20, No. 8, pp. 678-690.

(14) *Blackhurst, J.V., et al.* (2008): Supplier risk assessment and monitoring for the automotive industry, in: International Journal of Physical Distribution & Logistics Management, Vol. 38, No. 2, pp. 143-165.

(15) *Bottani, E./Rizzi, A.* (2006): Strategic management of logistics service: A fuzzy QFD approach, in: International Journal of Production Economics, Vol. 103, No. 2, pp. 585-599.
(16) *Büyüközkan, G./Çifçi, G.* (2011): A novel fuzzy multi-criteria decision framework for sustainable supplier selection with incomplete information, in: Computers in Industry, Vol. 62, No. 2, pp. 164-174.
(17) *Büyüközkan, G., et al.* (2009): Evaluation of 4PL operating models: A decision making approach based on 2-additive Choquet integral, in: International Journal of Production Economics, Vol. 121, No. 1, pp. 112-120.
(18) *Carrera, D./Mayorga, R.* (2008): Supply chain management: a modular Fuzzy Inference System approach in supplier selection for new product development, in: Journal of Intelligent Manufacturing, Vol. 19, No. 1, pp. 1-12.
(19) *Cebi, F./Bayraktar, D.* (2003): An integrated approach for supplies selection, in: Logistics Information Management, Vol. 16, No. 6, pp. 395-400.
(20) *Chan, F.T.S.* (2003): Interactive selection model for supplier selection process: an analytical hierarchy process approach, in: International Journal of Production Research, Vol. 41, No. 15, pp. 3549-3579.
(21) *Chan, F.T.S., et al.* (2003): A conceptual model of performance measurement for supply chains, in: Management Decision, Vol. 41, No. 7, pp. 635-642.
(22) *Chan, F.T.S./Chung, S.H.* (2004): A multi-criterion genetic algorithm for order distribution in a demand driven supply chain, in: International Journal of Computer Integrated Manufacturing, Vol. 17, No. 4, pp. 339-351.
(23) *Chan, F.T.S., et al.* (2008): Global supplier selection: a fuzzy-AHP approach, in: International Journal of Production Research, Vol. 46, No. 14, pp. 3825-3857.
(24) *Chan, F.T.S./Qi, H.J.* (2003): An innovative performance measurement method for supply chain management, in: Supply Chain Management: An International Journal, Vol. 8, No. 3, pp. 209-223.
(25) *Chang, S.-L., et al.* (2006): Applying fuzzy linguistic quantifier to select supply chain partners at different phases of product life cycle, in: International Journal of Production Economics, Vol. 100, No. 2, pp. 348-359.
(26) *Chantrasa, R./Ferrell, W., JR* (2005): A decision-making approach for information sharing in a supply chain, in: IIE Annual Conference. Proceedings, pp. 1-5.
(27) *Che, Z.H.* (2010): Using fuzzy analytic hierarchy process and particle swarm optimisation for balanced and defective supply chain problems considering WEEE/RoHS directives, in: International Journal of Production Research, Vol. 48, No. 11, pp. 3355-3381.
(28) *Chen, C.-T., et al.* (2006): A fuzzy approach for supplier evaluation and selection in supply chain management, in: International Journal of Production Economics, Vol. 102, No. 2, pp. 289-301.
(29) *Chen, Y.-M., et al.* (2011): Selection process in logistics outsourcing – a view from third party logistics provider, in: Production Planning & Control, Vol. 22, No. 3, pp. 308-324.
(30) *Chen, Y.-M./Huang, P.-N.* (2007): Bi-negotiation integrated AHP in suppliers selection, in: Benchmarking: An International Journal, Vol. 14, No. 5, pp. 575-593.
(31) *Chen, Y.-J.* (2011): Structured methodology for supplier selection and evaluation in a supply chain, in: Information Sciences, Vol. 181, No. 9, pp. 1651-1670.
(32) *Cheng, Y.-H./Lee, F.* (2010): Outsourcing reverse logistics of high-tech manufacturing firms by using a systematic decision-making approach: TFT-LCD sector in Taiwan, in: Industrial Marketing Management, Vol. 39, No. 7, pp. 1111-1119.

(33) *Choudhury, A.K., et al.* (2004): Application of an analytical network process to strategic planning problems of a supply chain cell: case study of a pharmaceutical firm, in: Production Planning & Control, Vol. 15, No. 1, pp. 13-26.
(34) *Chuu, S.-J.* (2011): Interactive group decision-making using a fuzzy linguistic approach for evaluating the flexibility in a supply chain, in: European Journal of Operational Research, Vol. 213, No. 1, pp. 279-289.
(35) *Cigolini, R./Rossi, T.* (2008): Evaluating supply chain integration: a case study using fuzzy logic, in: Production Planning & Control, Vol. 19, No. 3, pp. 242-255.
(36) *Dotoli, M., et al.* (2005): A multi-level approach for network design of integrated supply chains, in: International Journal of Production Research, Vol. 43, No. 20, pp. 4267-4287.
(37) *Efendigil, T., et al.* (2008): A holistic approach for selecting a third-party reverse logistics provider in the presence of vagueness, in: Computers & Industrial Engineering, Vol. 54, No. 2, pp. 269-287.
(38) *Erol, I., et al.* (2011): A new fuzzy multi-criteria framework for measuring sustainability performance of a supply chain, in: Ecological Economics, Vol. 70, No. 6, pp. 1088-1100.
(39) *Gaudenzi, B./Borghesi, A.* (2006): Managing risks in the supply chain using the AHP method, in: International Journal of Logistics Management, Vol. 17, No. 1, pp. 114-136.
(40) *Gnanasekaran, S., et al.* (2006): Application of analytical hierarchy process in supplier selection: An automobile industry case study, in: South Asian Journal of Management, Vol. 13, No. 4, pp. 89-100.
(41) *Göl, H./Çatay, B.* (2007): Third-party logistics provider selection: insights from a Turkish automotive company, in: Supply Chain Management: An International Journal, Vol. 12, No. 6, pp. 379-384.
(42) *Govindan, K./Murugesan, P.* (2011): Selection of third-party reverse logistics provider using fuzzy extent analysis, in: Benchmarking: An International Journal, Vol. 18, No. 1, pp. 149-167.
(43) *Ho, W., et al.* (2010): Multiple criteria optimization of contemporary logistics distribution network problems, in: OR Insight, Vol. 23, No. 1, pp. 27-43.
(44) *Kainuma, Y./Tawara, N.* (2006): A multiple attribute utility theory approach to lean and green supply chain management, in: International Journal of Production Economics, Vol. 101, No. 1, pp. 99-108.
(45) *Kanda, A., et al.* (2007): Coordination in supply chains: an evaluation using fuzzy logic, in: Production Planning & Control, Vol. 18, No. 5, pp. 420-435.
(46) *Kannan, G.* (2009): Fuzzy approach for the selection of third party reverse logistics provider, in: Asia Pacific Journal of Marketing and Logistics, Vol. 21, No. 3, pp. 397-416.
(47) *Kannan, G., et al.* (2009): 3PRLP's selection using an integrated analytic hierarchy process and linear programming, in: International Journal of Services Technology and Management, Vol. 12, No. 1, p. 61.
(48) *Kannan, G., et al.* (2009): Multicriteria group decision making for the third party reverse logistics service provider in the supply chain model using fuzzy TOPSIS for transportation services, in: International Journal of Services Technology & Management, Vol. 11, No. 2, pp. 162-181.
(49) *Kannan, G., et al.* (2008): An application of the analytical hierarchy process and fuzzy analytical hierarchy process in the selection of collecting centre location for the reverse logistics Multicriteria Decision-Making supply chain model, in: International Journal of Management & Decision Making, Vol. 9, No. 4, p. 350.

(50) *Kannan, G., et al.* (2008): Analysis and selection of green suppliers using interpretative structural modelling and analytic hierarchy process, in: International Journal of Management & Decision Making, Vol. 9, No. 2, p. 163.
(51) *Kayakutlu, G./Büyüközkan, G.* (2010): Effective supply value chain based on competence success, in: Supply Chain Management: An International Journal, Vol. 15, No. 2, pp. 129-138.
(52) *Kinra, A./Kotzab, H.* (2008): A macro-institutional perspective on supply chain environmental complexity, in: International Journal of Production Economics, Vol. 115, No. 2, pp. 283-295.
(53) *Kirkwood, C.W., et al.* (2005): Improving supply-chain-reconfiguration decisions at IBM, in: Interfaces, Vol. 35, No. 6, pp. 460-473.
(54) *Kirytopoulos, K., et al.* (2010): Multiple sourcing strategies and order allocation: an ANP-AUGMECON meta-model, in: Supply Chain Management: An International Journal, Vol. 15, No. 4, pp. 263-276.
(55) *Kirytopoulos, K., et al.* (2008): Supplier selection in pharmaceutical industry: An analytic network process approach, in: Benchmarking: An International Journal, Vol. 15, No. 4, pp. 494-516.
(56) *Korpela, J., et al.* (2002): An analytic approach to production capacity allocation and supply chain design, in: International Journal of Production Economics, Vol. 78, No. 2, pp. 187-195.
(57) *Korpela, J., et al.* (2001): An analytic approach to supply chain development, in: International Journal of Production Economics, Vol. 71, No. 1-3, pp. 145-155.
(58) *Korpela, J., et al.* (2001): Customer service based design of the supply chain, in: International Journal of Production Economics, Vol. 69, No. 2, pp. 193-204.
(59) *Ku, C., et al.* (2010): Global supplier selection using fuzzy analytic hierarchy process and fuzzy goal programming, in: Quality and Quantity, Vol. 44, No. 4, pp. 623-640.
(60) *Kuei, C.-H., et al.* (2008): Implementing supply chain quality management, in: Total Quality Management & Business Excellence, Vol. 19, No. 11, pp. 1127-1141.
(61) *Kulak, O./Kahraman, C.* (2005): Fuzzy multi-attribute selection among transportation companies using axiomatic design and analytic hierarchy process, in: Information Sciences, Vol. 170, No. 2-4, pp. 191-210.
(62) *Kull, T./Talluri, S.* (2008): A supply risk reduction model using integrated multicriteria decision making, in: IEEE Transactions on Engineering Management, Vol. 55, No. 3, pp. 409-419.
(63) *Kumar, S./Bisson, J.* (2008): Utilizing analytic hierarchy process for improved decision making within supply chains, in: Human Systems Management, Vol. 27, No. 1, pp. 49-62.
(64) *Kuo, R.J., et al.* (2010): Developing a supplier selection system through integrating fuzzy AHP and fuzzy DEA: A case study on an auto lighting system company in Taiwan, in: Production Planning & Control, Vol. 21, No. 5, pp. 468-484.
(65) *Kuo, R.J., et al.* (2010): Integration of artificial neural network and MADA methods for green supplier selection, in: Journal of Cleaner Production, Vol. 18, No. 12, pp. 1161-1170.
(66) *Lam, S.W./Tang, L.C.* (2006): Multiobjective vendor allocation in multiechelon inventory systems: a spreadsheet model, in: Journal of the Operational Research Society, Vol. 57, No. 5, pp. 561-578.
(67) *Liang, T.F.* (2008): Integrating production-transportation planning decision with fuzzy multiple goals in supply chains, in: International Journal of Production Research, Vol. 46, No. 6, pp. 1477-1494.

(68) *Lin, C.-T., et al.* (2006): Agility index in the supply chain, in: International Journal of Production Economics, Vol. 100, No. 2, pp. 285-299.
(69) *Liu, F.-H.F./Hai, H.L.* (2005): The voting analytic hierarchy process method for selecting supplier, in: International Journal of Production Economics, Vol. 97, No. 3, pp. 308-317.
(70) *Liu, P./Zhang, X.* (2011): Research on the supplier selection of a supply chain based on entropy weight and improved ELECTRE-III method, in: International Journal of Production Research, Vol. 49, No. 3, pp. 637-646.
(71) *Lorentz, H.* (2008): Production locations for the internationalising food industry: case study from Russia, in: British Food Journal, Vol. 110, No. 3, pp. 310-334.
(72) *Lu, L.Y.Y., et al.* (2007): Environmental principles applicable to green supplier evaluation by using multi-objective decision analysis, in: International Journal of Production Research, Vol. 45, No. 18/19, pp. 4317-4331.
(73) *Mafakheri, F., et al.* (2011): Supplier selection-order allocation: A two-stage multiple criteria dynamic programming approach, in: International Journal of Production Economics, Vol. 132, No. 1, pp. 52-57.
(74) *Makui, A., et al.* (2011): A method to compare supply chains of an industry, in: Supply Chain Management: An International Journal, Vol. 16, No. 2, pp. 82-97.
(75) *Masella, C./Rangone, A.* (2000): A contingent approach to the design of vendor selection systems for different types of co-operative customer/supplier relationships, in: International Journal of Operations & Production Management, Vol. 20, No. 1, pp. 70-84.
(76) *Min, H.* (2009): Application of a decision support system to strategic warehousing decisions, in: International Journal of Physical Distribution & Logistics Management, Vol. 39, No. 4, pp. 270-281.
(77) *Mukhopadhyay, S.K./Barua, A.K.* (2003): Supply chain cell activities for a consumer goods company, in: International Journal of Production Research, Vol. 41, No. 2, pp. 297-314.
(78) *Muralidharan, C., et al.* (2001): Vendor rating in purchasing scenario: a confidence interval approach, in: International Journal of Operations & Production Management, Vol. 21, No. 9/10, p. 1305.
(79) *Naesens, K., et al.* (2007): A swift response tool for measuring the strategic fit for resource pooling: a case study, in: Management Decision, Vol. 45, No. 3, pp. 434-449.
(80) *Naesens, K., et al.* (2009): A swift response framework for measuring the strategic fit for a horizontal collaborative initiative, in: International Journal of Production Economics, Vol. 121, No. 2, pp. 550-561.
(81) *Nobar, M., et al.* (2011): Selecting suppliers considering features of 2nd layer suppliers by utilizing FANP procedure, in: International Journal of Business and Management, Vol. 6, No. 2, pp. 265-275.
(82) *Noorul Haq, A./Kannan, G.* (2006): An integrated approach for selecting a vendor using grey relational analysis, in: International Journal of Information Technology & Decision Making, Vol. 5, No. 2, pp. 277-295.
(83) *Noorul Haq, A./Kannan, G.* (2006): Design of an integrated supplier selection and multi-echelon distribution inventory model in a built-to-order supply chain environment, in: International Journal of Production Research, Vol. 44, No. 10, pp. 1963-1985.
(84) *Noorul Haq, A./Kannan, G.* (2007): A hybrid normalised multi criteria decision making for the vendor selection in a supply chain model, in: International Journal of Management & Decision Making, Vol. 8, No. 5/6, pp. 601-622.

(85) *Ohdar, R./Ray, P.K.* (2004): Performance measurement and evaluation of suppliers in supply chain: An evolutionary fuzzy-based approach, in: Journal of Manufacturing Technology Management, Vol. 15, No. 8, pp. 723-734.
(86) *Ordoobadi, S.M.* (2010): Application of AHP and Taguchi loss functions in supply chain, in: Industrial Management & Data Systems, Vol. 110, No. 8, pp. 1251-1269.
(87) *Ounnar, F./Pujo, P.* (2005): Evaluating suppliers within a self-organized logistical network, in: International Journal of Logistics Management, Vol. 16, No. 1, pp. 159-172.
(88) *Parthiban, P., et al.* (2008): Logical approach for evaluation of supply chain alternatives, in: International Journal of Management & Decision Making, Vol. 9, No. 2, pp. 204.
(89) *Perçin, S.* (2008): Use of fuzzy AHP for evaluating the benefits of information-sharing decisions in a supply chain, in: Journal of Enterprise Information Management, Vol. 21, No. 3, pp. 263-284.
(90) *Platts, K.W., et al.* (2002): Make vs. buy decisions: A process incorporating multi-attribute decision-making, in: International Journal of Production Economics, Vol. 77, No. 3, pp. 247-257.
(91) *Rabelo, L., et al.* (2007): Value chain analysis using hybrid simulation and AHP, in: International Journal of Production Economics, Vol. 105, No. 2, pp. 536-547.
(92) *Ravi, V., et al.* (2008): Selection of a reverse logistics project for end-of-life computers: ANP and goal programing approach, in: International Journal of Production Research, Vol. 46, No. 17, pp. 4849-4870.
(93) *Ravindran, A.R., et al.* (2010): Risk adjusted multicriteria supplier selection models with applications, in: International Journal of Production Research, Vol. 48, No. 2, pp. 405-424.
(94) *Routroy, S.* (2009): Selection of third party logistics provider in supply chain, in: International Journal of Services Technology and Management, Vol. 12, No. 1, pp. 23.
(95) *Sarkar, A./Mohapatra, P.K.J.* (2006): Evaluation of supplier capability and performance: A method for supply base reduction, in: Journal of Purchasing & Supply Management, Vol. 12, No. 3, pp. 148-163.
(96) *Sarker, R./Zahir, S.* (2008): Supply chain expansion Using AHP, ILP and scenario-planning, in: Journal of American Academy of Business, Cambridge, Vol. 14, No. 1, pp. 21-29.
(97) *Sarkis, J.* (2003): A strategic decision framework for green supply chain management, in: Journal of Cleaner Production, Vol. 11, No. 4, pp. 397-409.
(98) *Sarkis, J./Talluri, S.* (2004): Evaluating and selecting e-commerce software and communication systems for a supply chain, in: European Journal of Operational Research, Vol. 159, No. 2, pp. 318-329.
(99) *Sarmiento, R./Thomas, A.* (2010): Identifying improvement areas when implementing green initiatives using a multitier AHP approach, in: Benchmarking, Vol. 17, No. 3, pp. 452-463.
(100) *Sarode, A.D., et al.* (2010): Improving effectiveness fo supply chain by selecting an appropriate supplier: An analytic hierachy process approach, in: Journal of Advanced Manufacturing Systems, Vol. 9, No. 2, pp. 129-144.
(101) *Schoenherr, T., et al.* (2008): Assessing supply chain risks with the analytic hierarchy process: Providing decision support for the offshoring decision by a US manufacturing company, in: Journal of Purchasing & Supply Management, Vol. 14, No. 2, pp. 100-111.
(102) *Selim, H., et al.* (2008): Collaborative production-distribution planning in supply chain: A fuzzy goal programming approach, in: Transportation Research. Part E, Logistics & Transportation Review, Vol. 44, No. 3, pp. 396-419.
(103) *Sevkli, M., et al.* (2008): Hybrid analytical hierarchy process model for supplier selection, in: Industrial Management + Data Systems, Vol. 108, No. 1, pp. 122-142.

(104) *Sha, D.Y./Che, Z.H.* (2006): Supply chain network design: partner selection and production/distribution planning using a systematic model, in: Journal of the Operational Research Society, Vol. 57, No. 1, pp. 52-62.
(105) *Sharma, M.K./Bhagwat, R.* (2007): An integrated BSC-AHP approach for supply chain management evaluation, in: Measuring Business Excellence, Vol. 11, No. 3, pp. 57-68.
(106) *Sheu, J.-B.* (2008): A hybrid neuro-fuzzy analytical approach to mode choice of global logistics management, in: European Journal of Operational Research, Vol. 189, No. 3, pp. 971-986.
(107) *Shore, B./Venkatachalam, A.R.* (2003): Evaluating the information sharing capabilities of supply chain partners: A fuzzy logic model, in: International Journal of Physical Distribution & Logistics Management, Vol. 33, No. 9, pp. 804-824.
(108) *Tonanont, A., et al.* (2008): Performance evaluation in reverse logistics with data envelopment analysis, in: IIE Annual Conference. Proceedings, pp. 764-769.
(109) *Torabi, S.A./Hassini, E.* (2009): Multi-site production planning integrating procurement and distribution plans in multi-echelon supply chains: an interactive fuzzy goal programming approach, in: International Journal of Production Research, Vol. 47, No. 19, pp. 5475-5499.
(110) *Tsai, W.H./Hung, S.-J.* (2009): A fuzzy goal programming approach for green supply chain optimisation under activity-based costing and performance evaluation with a value-chain structure, in: International Journal of Production Research, Vol. 47, No. 18, pp. 4991-5017.
(111) *Tseng, M.-L., et al.* (2009): Selection of optimal supplier in supply chain management strategy with analytic network process and choquet integral, in: Computers & Industrial Engineering, Vol. 57, No. 1, pp. 330-340.
(112) *Tseng, Y.-J./Lin, Y.-H.* (2005): A model for supplier selection and tasks assignment, in: Journal of American Academy of Business, Cambridge, Vol. 6, No. 2, pp. 197-207.
(113) *Varma, S., et al.* (2008): Evaluating petroleum supply chain performance, in: Asia Pacific Journal of Marketing and Logistics, Vol. 20, No. 3, p. 343.
(114) *Wadhwa, S., et al.* (2007): A network approach for modeling and design of agile supply chains using a flexibility construct, in: International Journal of Flexible Manufacturing Systems, Vol. 19, No. 4, pp. 410-442.
(115) *Wang, E.J., et al.* (2010): Analysis of outsourcing cost-effectiveness using a linear programming model with fuzzy multiple goals, in: International Journal of Production Research, Vol. 48, No. 2, pp. 501-523.
(116) *Wang, G., et al.* (2004): Product-driven supply chain selection using integrated multi-criteria decision-making methodology, in: International Journal of Production Economics, Vol. 91, No. 1, pp. 1-15.
(117) *Wang, S.-Y., et al.* (2009): Assessment of supplier performance based on product-development strategy by applying multi-granularity linguistic term sets, in: Omega, Vol. 37, No. 1, pp. 215-226.
(118) *Wei, C.-C., et al.* (2007): A comprehensive supply chain management project selection framework under fuzzy environment, in: International Journal of Project Management, Vol. 25, No. 6, pp. 627-636.
(119) *Wu, C., et al.* (2009): An analytic network process-mixed integer multi-objective programming model for partner selection in agile supply chains, in: Production Planning & Control, Vol. 20, No. 3, pp. 254-275.
(120) *Wu, D.D., et al.* (2010): Fuzzy multi-objective programming for supplier selection and risk modeling: A possibility approach, in: European Journal of Operational Research, Vol. 200, No. 3, pp. 774-787.

(121) *Yan, W., et al.* (2008): An integration of bidding-oriented product conceptualization and supply chain formation, in: Computers in Industry, Vol. 59, No. 2/3, pp. 128-144.
(122) *Yang, Y.H., et al.* (2010): An analytic network process approach to the selection of logistics service providers for air cargo, in: Journal of the Operational Research Society, Vol. 61, No. 9, pp. 1365-1376.
(123) *Zandi, F., et al.* (2011): A fuzzy group Electre method for electronic supply chain management framework selection, in: International Journal of Logistics: Research & Applications, Vol. 14, No. 1, pp. 35-60.
(124) *Zangoueinezhad, A., et al.* (2011): Using SCOR model with fuzzy MCDM approach to assess competitiveness positioning of supply chains: focus on shipbuilding supply chains, in: Maritime Policy & Management, Vol. 38, No. 1, pp. 93-109.

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