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A COMPARATIVE EMPIRICAL STUDY OF ANALYTIC HIERARCHY PROCESS AND CONJOINT ANALYSIS: LITERATURE REVIEW

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Abstract: *This paper is based on the main difference between conceptual and theoretical frameworks as well as literature review of comparative studies of two multi-criteria decision making methods (MCDM): Analytic Hierarchy Process (AHP) and Conjoint analysis. The AHP method represents a formal framework for solving complex multiatributive decision making problems, as well as a systemic procedure for ranking multiple alternatives and/or for selecting the best from a set of available ones. Conjoint analysis is an experimental approach used for measuring individual's preferences regarding the attributes of a product or a service. It is based on a simple premise that individuals evaluate alternatives, with these alternatives being composed of a combination of attributes whose part-worth utilities are estimated by researchers. Bearing in mind the quality of desired results, it must be dependent on the problems and aspects of research: knowledge of the MCDM methods, level of complexity (number of criteria), order effects, level of consistency, chooses the appropriate method.*

Key words: *Analytic Hierarchy Process, Conjoint analysis, multi-criteria decision making (MCDM) methods, literature review.*

1. Introduction

Decision making refers to the process of selecting an alternative, from a set of available ones, which resolves a given problem. The following elements can be distinguished in the decision-making issue: goals to be achieved by making a decision, criteria that measure the achievement of the goals, weights of the criteria that reflect their importance and alternatives within which the most desirable is to be selected (Anderson et al., 2012). A goal is to understand as the state of the system that is to be reached by making a decision. Criteria are the attributes describing alternatives and usually in the given decision-making issue not all the criteria are

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equally important. Their relative importance stems from the preferences of a decision maker, respectively, a respondent.

Decision making has increasingly been present in scientific research projects around the world recently, as it has become clear that the success of companies largely depends on the decisions made. When we say that a manager makes quality decisions, this means that these decisions are well thought out, made at the right time, and the realization of such decisions is precisely planned, all in order to maximize the effects that the decisions need to achieve.

Generally, a decision maker is exposed to an environment that is extremely complex and dynamic, being burdened with his paradigms and a series of influences which he, sometimes knowingly and sometimes unconsciously, includes into the decision-making process. The situation changes when a decision maker disposes with enough information about the problem and when the events related to the problem are certain, which implies full knowledge of the event or knowledge of the probability of the occurrence of an event.

The methods used in decision making can be classified into the two basic groups:

1. Single-criterion optimization methods
2. Multi-criteria optimization methods

Multi-criteria decision making can be divided into (Figueira et al., 2005):

1. MADM (Multiple Attribute Decision Making), and
2. MODM (Multiple Objective Decision Making).

Basic difference between the multiple attribute and the multiple objective decision making is reflected in the fact that in the multiple attribute decision making the best action is selected from the final set of previously defined actions described by explicit attributes, while in the multiple objective decision making the final set of objectives is defined on the basis of which the action which will fulfill defined objectives is selected.

Primarily because of their similarity, but also because of the wide applicability in the last years, in this paper, two techniques of multi attribute valuation are selected: the AHP method and the Conjoint analysis.

The AHP method is designed for a subjective assessment of multiple alternatives compared to multiple criteria, organized into a hierarchical structure. At the upper level the criteria are assessed, and alternatives based on the criteria are evaluated at the lower level. A decision maker gives its subjective assessment separately for each level and sub-level. According to these estimates pair comparison matrices are formed, which are based exclusively on subjective assessments. The AHP is a technique used to rank more alternatives and/or to select the best one from a set of available ones. Ranking/selection is performed in relation to the overall goal which is described through multiple criteria.

Conjoint analysis is based on the assumption that complex decisions are made not based on a single attribute, but on several attributes and their levels CONsidered JOINTly, hence the term conjoint. The technique can establish the relative values of particular attributes and identify the trade-offs the customers are likely to make in choosing a product and service and the price they are willing to pay for it.

The paper is organized as follows: the sections 2 and 3 describe Conjoint analysis and the AHP method, basic concepts, goals and the methodology of performance. Conceptual comparison and overview of the applications of the selected methods will be described in chapters 4 and 5. Finally, the main conclusions are summarized in section 6.

2. Conjoint analysis

Conjoint analysis is a multivariate technique used specifically to understand how a respondent's preferences are developed (Hair et al., 1995). More precisely the technique is used to gain insights into how individuals evaluate the total worth of a profile by combining the separate amounts of utility for each attribute level.

There are three basic major phases for conducting a Conjoint study. The first phase involves determining relevant attributes and the levels of each attribute. Lists of attributes describing single alternatives are called profiles (real or hypothetical) being presented to respondents who are invited to express their preference by rating or ranking these profiles.

The second phase involves design data collection of measuring individual preference and estimating respondent's utility functions. To determine the relative importance of different attributes to respondents, a relationship between the attributes' utility and the rated responses must be specified. The most commonly used model is the linear additive model. This model assumes that the overall utility derived from any combination of attributes of a given good or service is obtained from the sum of the separate part-worths of the attributes. Thus, respondent *i*'s (*i*= 1,…, *I*) predicted conjoint utility for profile *j* (*j* = 1 ,…, *J*)can be specified as follows (Kuzmanović et al., 2013a):

$$U_{ij} = \sum_{k=1}^{K} \sum_{l=1}^{L_k} \beta_{ikl} x_{jkl} + \varepsilon_{ij} \quad (1)$$

where:

xjkl is a (0,1) variable that it equals 1 if profile *j* has attribute *k* at level *l*, otherwise it equals 0

βikl– respondent *i*'s utility with respect to level *l* (L_k – the number of levels of attribute *k*)of attribute *k* (*K* – the number of attributes)

ε_{ij} – stochastic error term.

The parameters *βikl* (also known as part-worth utilities) are estimated by a regression analysis. The value of beta coefficients can be used: to indicates the amount of any effect that an attribute has on overall utility of the profiles; for preference-based segmentation; to calculate the relative importance of each attribute (importance value). Importance values are calculated by taking the utility range for each attribute separately, and then dividing it by the sum of the utility ranges for all of the factors (2). The results are then averaged to include all of the respondents (Kuzmanović et al., 2013).

Error! Objects cannot be created from editing field codes. (2)

where FI_{ik} is the relative importance that *i*th respondent assigned to the factor *k*. The results are then averaged to include all the respondents:

$$FI_k = \sum_{i=1}^{I} FI_{ik} \Big/ I, \quad k = 1, \ldots, K \quad (3)$$

If the market is characterized by heterogeneous customer preferences, it is possible to determine the importance of each attribute for each isolated market segment.

The last (third) phase involves market simulation to predict how buyers will choose among competing products and how their choices are expected to change as product features and/or price are varied.

3. The Analytic Hierarchy Process (AHP)

The Analytic Hierarchy Process – AHP is a multi-criteria decision making method that was developed by Saaty (1980). This method considers a given set of qualitative and/or quantitative criteria combines them through the decomposition of complex problems into a model that has the form of a hierarchy (goal, criteria, sub-criteria and alternatives). The main objective of AHP is ranking/selection of several alternatives made in relation to the set goal, as well as the choice of the best one from a set of available ones, in situations where decision-making involves a larger number of experts and criteria (Popovic et al., 2018).

The generalized method can be simply described as follows (Bhushan & Rai, 2007): Data are collected from decision makers in the pairwise comparison of alternatives on a qualitative scale. Decision makers can rate the comparison as equal, marginally strong, strong, very strong, and extremely strong. The pairwise comparisons of various criteria are organized into a square matrix. The diagonal elements of the matrix are 1. The criterion in the *i*-th row is better than criterion in the *j*-th column if the value of element (*i, j*) is more than 1; otherwise the criterion in the *j*-th column is better than that in the *i*-th row. The (*j, i*) element of the matrix is the reciprocal of the (*i, j*) element.

The principal eigenvalue and the corresponding normalized right eigenvector of the comparison matrix give the relative importance of the various criteria being compared. The elements of the normalised eigenvector are termed weights with respect to the criteria or sub-criteria and ratings with respect to the alternatives.

Therefore a comparisons made by AHP are subjective this method tolerates inconsistency through the amount of redundancy in the approach. If this consistency index (*CI*) fails to reach a required level then answers to comparisons may be re-examined (4) (Sener et al., 2010).

$$CI = (\lambda_{\max} - n) / (n - 1) \tag{4}$$

where $\lambda_{\max}$ max is the maximum eigenvalue of the judgment matrix. AHP calculates a consistency ratio (*CR*) comparing the consistency index (*CI*) with a random matrix (*RI*). Saaty (1980) suggests the value of *CR* should be less than 0.1.

Finaly, the rating of each alternative is multiplied by the weights of the sub-criteria and aggregated to get local ratings with respect to each criterion. The local ratings are then multiplied by the weights of the criteria and aggregated to get global ratings.

It should be noted that AHP is a method that orders the priorities in a given situation, incorporating the element of subjectivity and intuition so that a final decision can be reached by experts for part-issues in a consistent way and gradually move up levels to deal with the given situation have clear idea of what it entails (Al-Harbi, 2001).

4. Conceptual comparison of AHP and Conjoint analysis

Both the Conjoint analysis and the AHP method can be used to measure preferences of respondents and determine relative importance of attributes (criteria),

but having in mind the quality of the desired results, a more appropriate method should be selected based on the specific problem and the research conditions. Basic theoretical differences between the Traditional Conjoint analysis and the AHP method are provided in the Table 1.

Table 1. Conceptual comparison of AHP and Conjoint analysis (Mulye, 1998; Helm et al., 2004; Scholl et al., 2005; Kallas et al., 2011)

	Conjoint analysis	**AHP**
Pre-condition	Preferential independence of the attributes	Preferential independence of the attributes
Survey form	Decompositional	Compositional
Scale used	Ordinal or interval scale	Ratio scale
Utility model	Additive part-worth model	Weighted additive utility model
Applicability	Up to six attributes with two to four levels	Many attributes possible with up to seven to eight attribute-levels
Respondents	Market segment on basis of individual customers	Individual decision makers
Interview expense	Ranking, rating or paired comparisons	Paired comparisons
The basic aim of application	Measuring preferences	Decision making
Application range	Design problems	Selection problems and/or design problems
Results	Part-worths of all attribute-levels	Relative preferences of attribute-levels and attributes

Although both techniques were developed with a different aim, they can be used in the same study. Fundamental assumption on which both methods are based is the preferential independence of the attributes, i.e., one level of attributes (for example, a brand) has no influence on the characteristics of another level of attributes (for example, on color). Conjoint analysis can function also in some cases of mutual interaction of attributes, but at least basic preferential independence is required.

Considering the AHP evaluation task is based on direct paired comparisons of single attributes and attribute levels, it is possible to survey tasks consisting of many attributes and their levels. But, Conjoint analysis asks the respondents to evaluate complete profiles. Therefore, the number of profiles and the number of attributes and their levels are limited as cognitive resources of the respondents are restricted. The differences in the scales used to evaluate the criteria cause differences in the evaluation steps. Both the AHP method and the Conjoint analysis are based on comparative analysis, but in the Conjoint analysis other evaluation steps are also possible.

Both methods are applicable for studies which use 'pen and paper' method, however, in the case of application of the AHP method, it is recommended the use of commercial softwares (www.expertchoice.com) which, during the evaluation process itself, determine consistency level of the responses and require that the responses to

the same questions are repeated in case of too large inconsistencies. The number of respondents is not limited, and the only difference is that the target group in the AHP method are the respondents representing individual decision makers (most often they are experts in a given field of research), and in the Conjoint analysis, these are arbitrarily chosen market segment.

There are several factors - such as the motivation of respondents, the scope of information that a questionnaire contains, the clarity of a questionnaire, the knowledge of the method - which can influence the results of empirical research using the AHP method and the Conjoint analysis. These factors determine practical applicability of the method; so for example, the questionnaires that are difficult to answer can reduce the validity of the results (Hartmann & Sattler, 2004). Likewise, the time needed to complete the questionnaire affects the results obtained. Longer questionnaires can exhaust the respondents, cause response distortion or provoke deviations in the study. Time is also a factor that affects total costs, as the total costs of conducting research increase by increasing the time required. The question arises as to what was the influence of the factors, such as the knowledge of the methods by the respondents, the complexity of the study (number of criteria) and the problem of research, to the result of the comparison of these methods.

5. Overview of the research projects based on the comparison of the AHP method and the Conjoint analysis

In the research projects based on the comparison of the Conjoint analysis and the AHP method are obtained contradictory conclusions regarding the conditions of application of these methods. Therefore, in order to compare them (during the application procedure), it is necessary to control all the factors that can favor one against the other method. Further in the paper, comparative overview of basic concepts of eight studies aimed at comparing the results of the Conjoint analysis and the AHP method (Table 2) will be presented.

Table 2. Overview of basic concepts of the research of comparison of the Conjoint analysis and the AHP

	Decision problem	**Number of attributes and attribute levels**	**Respondents**	**Complexity of the decision problem**
Tscheulin (1991)	Ship travels	5 attributes (4 with 3 and 1 with 4 levels)	No knowledge of the methods	Relatively complex
Mulye (1998) I study	Running shoes	4 attributes (2 with 3 and 2 with 4 levels)	Knowledge of the methods (students)	Relatively simple
Mulye (1998) II study	Rental accomodation	8 attributes (each consisting 3 levels)	Knowledge of the methods (students)	Relatively complex
Helm et al. (2004)	Universities	6 attributes (5 with 3 and 1 with 2 levels)	Knowledge of the methods (students)	Relatively complex
Helm et al. (2008)	Mountain bikes	4 attributes (po 3 levels)	Two groups– with/without	Relatively simple

	Decision problem	Number of attributes and attribute levels	Respondents	Complexity of the decision problem
			knowledge of the methods	
Ijzerman et al. (2008)	Treatment preferences in people with neurological disorders	7 attributes (2-4 levels)	No knowledge of the methods	Relatively complex
Kallas et al. (2011)	Rabbit meat in menus in Spain	4 attributes (each consisting 3 levels)	No knowledge of the methods	Relatively simple
Ijzerman et al. (2012)	Stroke rehabilitation	8 attributes (2-4 levels)	No knowledge of the methods	Relatively complex
Danner et al. (2017)	Age-Related Macular Degeneration	5 attributes (1 with 4, 2 with 3 and 2 with 2 levels)	No knowledge of the methods	Relatively complex

Danner et al., (2017) claim that common application of the AHP method and the Conjoint analysis is the broadest in the field of health care system. However, on the basis of comparative overview of fundamental concepts of the research carried out so far, as shown in the Table 3.6, it can be noted that the spectrum of the decision making issues is broad. According to the research issue, the studies conducted differ in complexity of the decision-making issue. Authors use four to eight attributes with two, three, four, or even five levels to describe their research issue. Taking into consideration the limitations of the application of the Conjoint analysis based on the number of attributes, certain decision-making issues can be characterized as relatively complex.

Although the study conducted by Kallas et al., (2011) did not have as the primary goal determining which method was better, the results obtained allowed them to see the advantages and disadvantages of each of the method. The AHP method proved to be easier in this study, while the Conjoint analysis allowed combining the obtained preferences with socio-demographic variables.

An important prerequisite for the quality of the obtained empirical results, stated by the authors in their papers, is the knowledge of the method (procedure) of the research by the respondents. In the Table 3 is provided an overview of the effects of comparison of the Conjoint analysis and the AHP based on the knowledge of the research methods and the complexity of the questionnaires found in the previous studies (Table 2).

As can be seen from the Table 3, the studies showed that different results were obtained if respondents knew the methods and understood the procedure: the Conjoint analysis appeared to be better when the respondents were not familiar with the research methodology, while the AHP should be opted for when respondents understand the steps of the method. Tscheulin (1991) suggests explaining some of the relevant methodological aspects of the AHP and the Conjoint analysis before the

interview itself. This can be performed as a "pre-research" through several minor and simpler common decision-making issues.

Table 3. Influence of knowledge of methods and complexity of questionnaires on the results of research (Helm et al., 2008; Ijzerman et al., 2012)

		Complexity of the evaluation task	
		HIGH/MEDIUM	LOW
Knowledge in preference measurement	YES	AHP better (II study -Mulye, 1998; Helm et.al., 2004)	Similar results (I study - Mulye, 1998) Conjoint analysis slightly better (Helm et.al., 2008)
	NO	Conjoint analysis better (Tscheulin, 1991; Ijzerman et al. 2012)	Conjoint analysis remarkably better (Helm et.al., 2008)

Given the consistency level achieved with the Conjoint analysis and the AHP method in all studies, the lower levels are less preferred. If sensitivity and consistency level are observed, the obtained results disagree. Although Helm et al., (2004) found in the first study that the AHP was less sensitive compared to the Conjoint analysis, in the second study (Helm et al., 2008) they came to the opposite conclusion. The Conjoint analysis proved to be less sensitive to changes and required a lower minimum level of consistency than the AHP, hence a large number of insufficiently consistent respondents in the study. The explanation of this difference is not obvious, but it may again result from a change in the complexity of the decision-making issues, because the inconsistency in the Conjoint analysis has much more direct impact on the final result than the local inconsistency in the AHP, which only applies to one attribute.

Considering other factors that influence the result of the comparison, it can be said that the Conjoint analysis leads to better results when applied after the AHP (Mulye, 1998). Helm et al., (2004), in contrast to Mulye, obtains opposite results, which is probably the consequence of the complexity of the problem, in the first study, however, in the second study based on somewhat simpler issues, slightly better effects can be observed when the Conjoint analysis is applied after the AHP (Helm et al., 2008).

The conclusion of a former research summarize the four aspects may influence the quality of the results of Conjoint analysis and AHP as technique for measuring preferences:

- knowledge of the MCDM methods,
- level of complexity (number of criteria),
- order effects,
- level of consistency.

It can be said that Conjoint analysis is a better choice in relatively simple decision-making issues. In case of complex decision-making problems and/or respondents with prior knowledge of the method of research, the AHP seems to be more convenient method. Having in mind practical applicability, the AHP method has a

potential advantage because it requires less time to complete the survey and achieve a higher level of satisfaction of the respondents (Helm et al., 2008; Ijzerman et al., 2012). Both methods require certain level of consistency in respondents' responses, with the Conjoint analysis being more resistant in simple, and the AHP in more complex issues. In any case, any "pre-research" performed before starting evaluation could have positive effects.

These findings could have an influence on future practice of measuring preferences, since more than 65% of all Conjoint analysis surveys include more than six attributes. Therefore, researchers need a new method that supports operating with multiple attributes. Many of the newly developed variants of the Conjoint analysis have failed in practice because there have been no commercial softwares to support them. Today, currently available Adaptive Conjoint analysis softwares are so far the most dominant commercial softwares that can compensate these deficiencies of the Traditional Conjoint analysis. Additionally, with the professional AHP-based softwares, more advanced options for measuring preferences appear in practice. Another advantage of the Conjoint analysis in relation to the AHP is that it offers the possibility of segmentation based on the results obtained, as well as the prediction of market share, which has not been taken into account by the authors of the previous studies.

6. Conclusions

The findings of this paper are significant on both a theoretical and an applied level. On a theoretical level, both methods can be applied in the measurement of the preferences of respondents and determining relative importance of attributes (criteria), but considering the quality of the required results, it is necessary based on the specific issue and the aspect of research (knowledge of the MCDM methods, level of complexity (number of criteria), order effects, level of consistency) to choose the adequate method. On the applied level, the results provide information to policy makers to help them make decisions more effectively. In fact, although these two methods were originally developed with different objectives, they can still be used independently in similar or the same research projects.

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