
Application of the Analytic Hierarchy Process (AHP) for Selection of Forecasting Software

Altug Pekin, Gamze Ozkan, Onur Eski, Umut Karaarslan,

Gurdal Ertek, Kemal Kilic

Sabanci University, Faculty of Engineering and Natural Sciences,

Orhanli, Tuzla, 34956, Istanbul, Turkey

Abstract

In this paper, we described an application of the Analytic Hierarchy Process (AHP) for the ranking and selection of forecasting software. AHP is a multi-criteria decision making (MCDM) approach, which is based on the pair-wise comparison of elements of a given set with respect to multiple criteria. Even though there are applications of the AHP to software selection problems, we have not encountered a study that involves forecasting software. We started our analysis by filtering among forecasting software that were found on the Internet by undergraduate students as a part of a course project. Then we processed a second filtering step, where we reduced the number of software to be examined even further. Finally we constructed the comparison matrices based upon the evaluations of three "semi-experts", and obtained a ranking of forecasting software of the selected software using the Expert Choice software. We report our findings and our insights, together with the results of a sensitivity analysis.

Submission areas: **Management Information Systems, Decision Support Systems, Enterprise Systems**

Introduction

Forecasting is a fundamental activity carried out by almost every company, regardless of the branch of industry, geographical location, size of the company, market structure and other aspects. A good forecast should be timely, accurate, reliable and cost-effective (Stevenson, 2005, Ch. 4). Three basic approaches to forecasting are judgmental forecasting, time-series forecasting and forecasting through associative models. The focus of our study is time-series forecasting software, which take historical data as input and make projections of future values through application of various methods including Holts Exponential Smoothing, Winter's Method and ARIMA.

There exists a multitude of forecasting software available in the market. Some of the software products have their trial versions available on the Internet. Considering the fact that the number of products produced and sold by companies has shown a dramatic increase in recent decades, it is almost inevitable for today's decision makers to receive the assistance of forecasting software, which can typically perform forecasting of time-series data in a matter of seconds. In this vein, a critical decision to make is the appropriate selection of the most suitable forecasting software.

In this paper we describe a study which provides guidance in selection of the "best" forecasting software through the Analytic Hierarchy Process (AHP). We first introduce the AHP including a discussion of relevant issues that have to be taken into consideration while employing it. Next, we express the steps that we followed in our study, including a discussion of how we decided on a small subset of software available on the Internet and how we decided on the criteria that will be used during the evaluation. Then we illustrate our application of the AHP using Expert Choice software[1], presenting our findings and insights, and performing a sensitivity analysis. Finally, we present a brief review of related literature, draw our conclusions, and outline possible research areas.

The Analytic Hierarchy Process (AHP)

The AHP is concerned with a model that reflects the decision problem's major components (such as decision criteria) and their inter-connections (such as comparisons with each other). It functions via breaking the problem into several sub-categories and blending the results and solutions of those sub-categories in a very systematic manner. Used in numerous applications of decision making throughout the world, the process relies on focusing on the goal of the problem and having adequate knowledge in each of the categories. It operates as a complete model, signifying the relations of importance, dominance, and preference among the aspects of the problem.

In AHP, a problem is structured as a hierarchy, where a decision is met by decomposing the goal into the most general and most easily controlled factors. In our problem, we have only a single-level hierarchy of decision criteria; therefore we applied the AHP in its most basic form.

[1] http://www.expertchoice.com/

As suggested by Saaty (1994), a judgment or comparison is the numerical representation of a relationship between two elements that share a common parent. The set of all relative judgments are then reported in a square matrix, in which the elements are compared with each other. As highlighted in Table 1, the judgments, in a scale ranging from 1 to 9, correspond to the level of dominance or contribution to the project. On the contrary, if the element on the vertical scale of the matrix possesses relatively less importance over the element located on the horizontal scale, we enter the reciprocal values of these scores. It is also important that in comparisons elements with less importance are regarded as the unit.

Table 1.

Given values (1-9)	*Explanation*
1 Equal	Both alternatives have equal importance.
3 Moderate	One of the alternatives is slightly more important than the other.
5 Strong	One of the alternatives is judged as strongly more important than the other by experts.
7 Very Strong	One of the alternatives is judged as very strongly important compared to the other.
9 Extreme Importance	One alternative is strictly superior to the other one.
2, 4, 6, 8 Intermediate values	Used for compromised judgments when necessary.

Our efforts in preparing these square matrices made us realize that judgments are not always consistent with each other. "In eliciting judgments, one makes redundant comparisons to improve the validity of the answer, given that respondents may be uncertain or may make poor judgments in comparing some of the elements. Redundancy gives rise to multiple comparisons of an element with other elements and hence to numerical inconsistencies" (Saaty, 1994). Generally, inconsistency is considered as a tolerable error when the variance does not exceed 10% of the original value. On the contrary, inconsistencies with higher percentages would lead to severe problems in the hieratical process. One of the most important factors that make AHP successful is that, it can highlight which judgments are the most inconsistent in sequential order. It also attempts to improve the consistency.

"Priorities are numerical ranks measured on a ratio scale. A ratio scale is a set of positive numbers whose ratios remain the same if all the numbers are multiplied by an arbitrary positive number" (Saaty, 1994). The process is initiated by obtaining the local priorities, which are originated from the judgments concerning a single criterion. Then they are transferred to global priorities obtained from the respective weight of each criterion.

Lastly, there are several factors that make AHP distinguishable from its alternatives such as spanning tree matrix, bubble sort, binary search tree and priority groups (Karlsson, 1998). One of these factors is that by taking perspectives of users into consideration by enabling differences in opinion, the software tries to create an accepted consensus. Calculating the geometric mean of evaluations of each expert, the AHP combines the separate judgments into a complete conclusion. Even though constructing an AHP model requires eliciting of extensive data from a group of respondents, and is thus time consuming in this respect, it is fairly insensitive to judgmental errors (Karlsson, 1998).

AHP has been applied to a great variety of decision making problems in a multitude of domains. Vaidya and Kumar (2006) provide an overview of more than 150 AHP applications, and analyze 27 of them in detail. We summarize the applications that are closely related to our study in the *Related Literature* section.

The Steps in Our Study

In our study, we followed the steps below:

1. We started our study by compiling evaluations of forecasting software that were submitted as a part of an introductory industrial engineering course's projects given to

sophomore students at Sabanci University. Among ~100 projects, 48 of them (that received >40 out of 50) were taken into consideration. Each project contained a list of five favorite forecasting software scored and ranked by group members. This compilation resulted in a list of 24 software products.

2. The obtained software list was reduced to a smaller list of 13 software products, based on popularity by the groups and the availability of the trial versions on the Internet.

3. The filtered 13 software products were filtered through testing on a dataset that exhibits trend and strong seasonality (with extremely high values for December)[2]. The dataset consists of the monthly sales quantities of champagne. Other criteria in this second filtering stage were ease of use, steepness of the learning curve and numerical accuracy. The final list contained only six software products, which will be listed when the AHP results are discussed. Our approach is radically different from Tashman and Hoover (2001). They initially classify forecasting software into the four categories of spreadsheet add-ins, forecasting modules of broad-scope statistical programs, neural networks, and dedicated business-forecasting programs, and review a number (3 to 5) of software products (15 in total) from each of these categories. Throughout their study they establish contact with the software vendors. We did not follow such a classification approach and have not contacted any software vendors in our study. Among the six software products that we consider in the AHP model, only the Minitab software exists in the software list of Tashman and Hoover (2001).

4. The six software products were compared pair-wise by three respondents with respect to seven criteria derived from forecasting literature. Meanwhile the weights that denote the importance of each criterion were determined by group consensus.

5. The comparison matrices and the weights for criteria were input into the Expert Choice software. Expert Choice computed the priorities and thus the ranking of the software products, which we take as guidelines for comparing the software products.

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[2] We have used the dataset titled montgome11.dat from “Time Series Data Library” website. The dataset originally comes from Montgomery and Johnson (1976). The file containing the dataset can be downloaded from the “Sales” link at the following site:
http://www-personal.buseco.monash.edu.au/~hyndman/TSDL/

The last two steps are explained in detail in the next section.

Applying the AHP Method

The initial step in applying the AHP method is "structuring the problem with a model that shows the problem's key elements and their relationships" (Saaty, 1994). At this step, one decides on the criteria that will be used to evaluate the alternatives.

In our study, we identified seven criteria for which we built the comparison matrices (Figure 1). Six of these criteria are derived from Tashman and Hoover (2001), which are data preparation, method selection, method implementation, method evaluation, assessment of uncertainty and forecast presentation. These criteria are explained in detail in the mentioned article. Tashman and Gros (2001) summarize these criteria by listing the sub-criteria for each. We have used only the six main criteria, not delving into the sub-criteria. The reason for this choice was that it would take way too much time to consider all the sub-criteria. The seventh criterion that we selected, namely the ease of use, comes from an article by Sanders and Manrodt (2003): In a survey carried out at 240 US corporations the authors have found out that "ease of use" was the most important feature by managers (selected by ~86% of them) in using forecasting software.

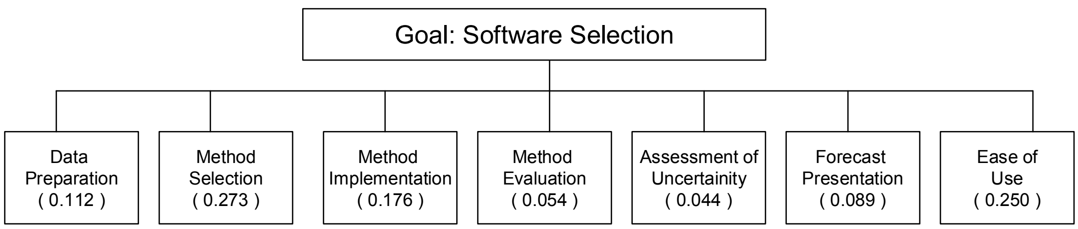

Figure 1. The Selection Criteria in Our AHP Study

The second step in applying the AHP method is eliciting judgments of experts and representing them in comparison matrices for the elements with respect to the selected criteria and a comparison matrix to compare the criteria with each other. At this step of our study, we have elicited the evaluations of three “semi-experts”. These respondents were three of the authors of this paper, who are also sophomore students at Sabanci University. The respondents had completed the course project with great success and were believed by their instructor (who is also one of the authors of this paper) to be highly capable of learning and efficiently using new software products quickly. The judgments of these respondents were combined in constructing the decision making model in Expert Choice. The comparison matrix for the seven criteria is shown in Figure 3.

	Data prep	Method sel	Method im	Method ev	Forecast p	Uncertainty	Ease of Us
Data prep		4,0	2,0	2,0	2,0	4,0	3,0
Method selection			2,0	4,0	3,0	4,0	1,0
Method implementation				4,0	2,0	5,0	2,0
Method evaluation					2,0	1,0	3,0
Forecast presentation						3,0	3,0
Uncertainty assesment							4,0
Ease of Use	Incon: 0,03						

Figure 3. The Matrix Constructed by the Respondents
for the Comparison of the Seven Criteria

The third step involves calculating the priorities of the elements, which in our case are forecasting software products. Expert Choice provides helpful features at this stage of the process in terms of applying the comparison matrices and leading a way to the determination of the priority among the given alternatives. Some other advantages of the Expert Choice software are praised by Lai et al. (2002).

When deciding on the selection criteria, we could not include two important criteria that would normally be considered in a decision making process, since they are totally objective. These criteria are price (for single-user commercial license) and country of origin (which could be considered with respect to receiving telephone support). Another criterion that we believe is important is the capability to perform data import/export from/to MS Excel. Luckily, all the products that we have selected offer this capability. We display the data for price and country of origin in Table 2 together with the priorities for the seven included criteria.

Table 2 provides a ranking of the software products. NCSS, DecisionPro and Minitab have comparably higher priorities than the other three software products according to the AHP model. However, the Forecasting Tool software distinguishes itself among all by its very low price. Clearly one can gain more insights from further analysis, which we present below.

Table 2. The Priorities Computed by Expert Choice Software and the Values of Criteria Excluded from the AHP Model.

Software Name	*Priority*	*Price*[3]	*Country of Origin*
NCSS	0.255	$600	USA
DecisionPro	0.232	$795	USA
Minitab	0.197	$1195	USA
Forecasting Tool[4]	0.129	$75	USA
Aura	0.099	$441	Russia
Systat	0.088	$1299	USA

Insights

Performance Sensitivity graph for the model is presented in Figure 4, where data for each of the six software products is shown with a different color. On the x-axis, one can see the seven criteria used in the model, and on the right-hand-side y-axis one can see the overall scores of all the software products (alternatives). The sum of these overall scores is equal to 1, in accordance with the AHP methodology.

Even though the DecisionPro software is clearly the best with respect to "Method selection", NCSS ranks as the top software product, since it has the highest scores with respect to all the

[3] The prices are retrieved in October 2005 and are rounded to the nearest integer.
[4] This product is a MS Excel Add-In.

other criteria (except "Uncertainty assessment", where Minitab is superior). NCSS is also observed to exhibit superiority with respect to "Forecast precision" criterion, together with the Aura software. Thus these two software products are suitable for companies which compete in industries where predicting the customer demands are extremely crucial to survive. Companies that produce expensive products or operate under tight production and distribution constraints can adopt these software alternatives. When compared to NCSS, the Aura software is inferior with respect to all the criteria, so one could tend to select NCSS rather than Aura. However, the Aura software could be a great alternative –with its high forecasting precision- for Russia and Russian-speaking countries.

Forecasting Tools software, which is the lowest-price alternative is also distinguished by its highest score with respect to the "Ease of use" criterion. However, it is judged to be worse compared to other products with respect to other criteria. This property of Forecasting Tools software can suggest that this tool is suitable for smaller companies with non-technical people carrying out the forecasts. This tool can also be adopted by educational institutions due to its low price.

It should be re-iterated again that the Minitab software exhibits a great advantage compared to other software packages with respect to "Uncertainty assessment". Thus this software can be very suitable to use by companies that operate under high levels of demand uncertainty.

Sensitivity Analysis

In Figure 4, the bars situated on the x-axis show the relative importance given to each of the seven criteria by the decision maker (whose values are shown on the left-hand-side y-axis). The decision maker can interactively change the length of these bars with the mouse and observe how the ranks and priorities of the software products change. As the length of a bar increased, the weight of the corresponding criterion is increased. For example, when the height of the bar corresponding to the criterion "Method selection" (the second bar from the left) is increased enough, DecisionPro software becomes the best software, as shown in Figure 5. The reason is that the weight of the "Method selection" criterion, where DecisionPro dominates, is increased in the graph.

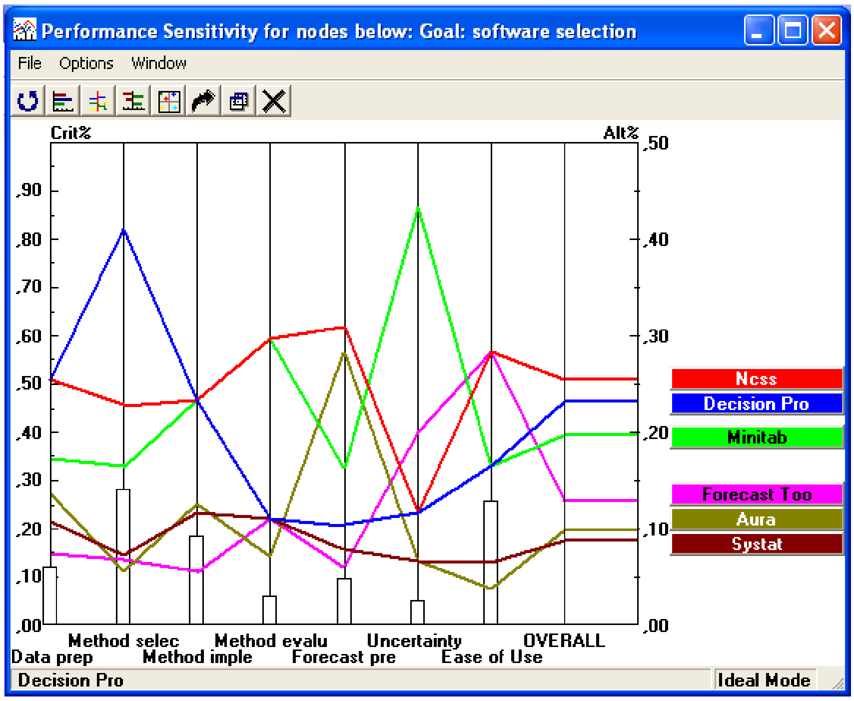

Figure 4. Performance Sensitivity Graph Provided by Expert Choice Based on the Original Data Provided by the Respondents.

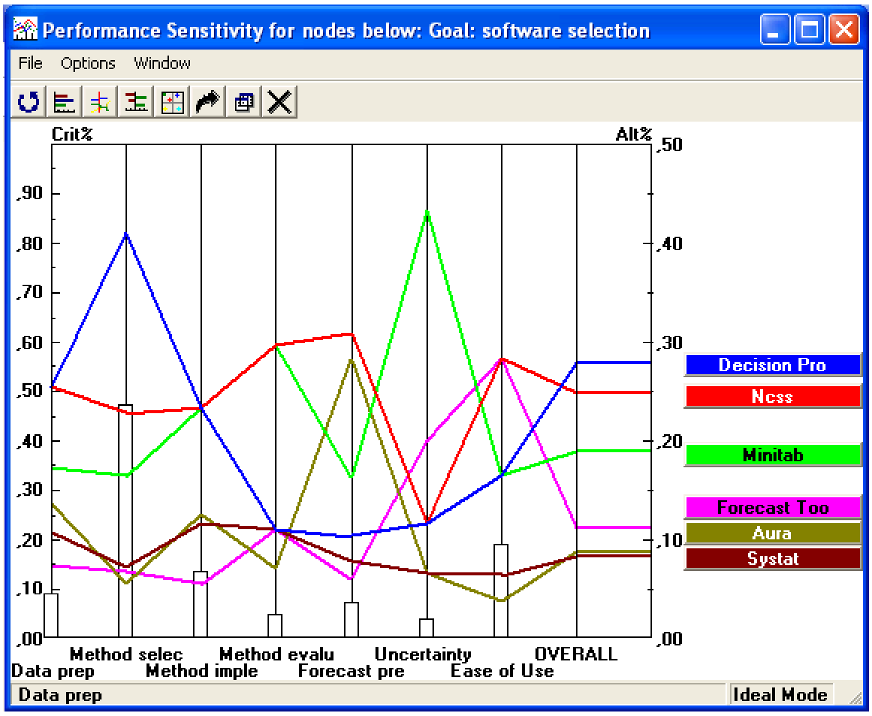

Figure 5. Performance Sensitivity Graph Changes When the “Method selection” Bar is Interactively Raised, Elevating DecisionPro to the Top Position.

Related Literature

One of the main motivations of this study was the absence of a work in literature that employs a methodological approach –such as AHP- for evaluating and comparing forecasting software. It is typical to find "Software Reviews" articles in forecasting journals (such as *International Journal of Forecasting* and *Journal of Forecasting*), focusing on a single software product. The article by Tashman and Hoover (2001) is the only study that gives general insights and suggestions, besides ratings of the software products and the categories. However they have omitted criteria such as ease of learning, easy of use by decision makers who possess only a modest statistical background, complexity of user interfaces, and price. We consider all -but the last one- of these criteria in the two filtering stages. When compared with Tashman and Hoover (2001), our study takes as audience the decision maker with less technical knowledge who has limited time to test various software.

Application of the AHP method to selection of various types of software can be found in literature:

- Ossadnik and Lange (1999) evaluate three AHP software products through an AHP-based study. They suggest using the international norm ISO/IEC 9126 as a baseline to identify criteria in measuring software quality.
- Lai et al. (2002) present a case study that six software engineers participated which involved selection of a multi-media authorizing system. They report a post-study survey that revealed that the AHP was more preferable than Delphi as a group-decision making method.
- Jung and Choi (1999) use AHP to derive weights of software modules –based on access frequencies of the modules- that are then used in optimization models. The optimization models deal with selecting the best software modules when building larger software.

Conclusions

We have applied the AHP in selecting forecasting software, introducing the use of the AHP to the forecasting literature for the first time, to our knowledge. In this paper we explained the steps that we have followed in our study and shared our insights with respect to which software products would be most appropriate for which types of companies. We also showed through sensitivity analysis how the weights given to decision criteria can change the priorities and rankings of the software products.

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Appendix

List of the 23 software products downloaded and tested, out of which six were filtered for the AHP study (listed in alphabetical order):

Number	*Software Name*	*Company Web Site*	*Country of Origin*	*Price (US $)*
1	Alyuda Forecast XL	http://www.alyuda.com/	USA	149
2	Alyuda Forecaster	http://www.alyuda.com/	USA & UK	-
3	Alyuda NeuroIntelligence	http://www.alyuda.com/	USA & UK	-
4	Aura	http://www.stockfusion.net/aura/index.html	Russia	441
5	Autobox	http://www.autobox.com/autobox	USA	5000
6	Caster	http://stockfusion.net/caster.html	Russia	20
7	Cyrstal Ball Predictor	http://www.crystalball.com/downloadcb.html	USA	45
8	Decision Time	http://www.spss.com/decisiontime/	USA	999
9	DecisionPro	http://www.vanguardsw.com	USA	795
10	Equivtest	http://www.statsol.ie/	USA	675

11	Exlplan	http://www.planware.org	Ireland	49
12	FENIX	http://www.abyaingenieros.com	Colombia	580
13	Forecasting Tools	http://www.mgmoreira.com	USA	75
14	ForecastPro	http://www.forecastpro.com/products/fpfamily/index.html	USA	595
15	FreeFore	http://www.autobox.com	USA	1995
16	Hom 3.0	http://pages.stern.nyu.edu/~sseshadr/hom/	USA	-
17	MARS	http://www.salford-systems.com	USA	-
18	MiniTab14	http://www.minitab.com	USA	1195
19	NCSS	http://www.ncss.com	USA	600
20	PHICAST	http://www.buseco.monash.edu.au/units/forecasting	Australia	550
21	Statgraphics Centurion	http://www.statvision.com/.	USA	695
22	StatTools	http://www.palisade-europe.com	USA	295
23	SYSTAT11	http://www.systat.com/	USA	1299
24	XL Stat - Pro	http://www.koycomp.co.uk/	UK	395