AHP Based Decision Support: European Case Studies

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Abstract
After a brief review of the basic principles of the AHP methodology the paper concentrates on the presentation of some European case studies that relate to Business Administration and Politics.
The first practice report shows the ranking of 20 European MBA schools which have been subjected to a simple ranking procedure (absolute measurement scale). In addition, the 3 top schools are analysed from the viewpoint of a prospective MBA candidate (relative measurement). The second study is mainly concerned with the reappraisal of original expert judgements. It relates to the American presidential elections of 1992 and the corresponding follow-up studies.

Keywords
AHP, Business Administration, European practice, measurement (absolute/relative), Politics, software.

A brief survey of the OR literature of the last decade shows that few topics have received as much attention as **multi-criteria decision analyses**. They have become a central topic of research and a favorite theme at OR conferences around the world.

Multi-criteria decision analyses can be of the **multi-objective or multi-attributive type**, whereby the latter would also include the **AHP methodology**.

AHP (Analytic Hierarchy Process) has been developed by Thomas L. Saaty and a group of researchers around him (5-10; 2-3). In recent years, it has also become a central topic of **Management Science courses** at European universities and, as a consequence, AHP is well presented in modern OR/MS textbooks (4, 11-13). Furthermore, **case studies** have been widely observed by practising managers looking for new and powerful decision support techniques.

The following discussion provides some insights into **European developments** in the AHP field.

1 AHP in Management Education

Management education programs should acquaint the participants with the **basic AHP techniques**, exemplify them by case studies of various complexity, augment the course by a **survey of generally available AHP software packages**, and ultimately lead to the elaboration of practice oriented **problems**.

11 AHP Techniques

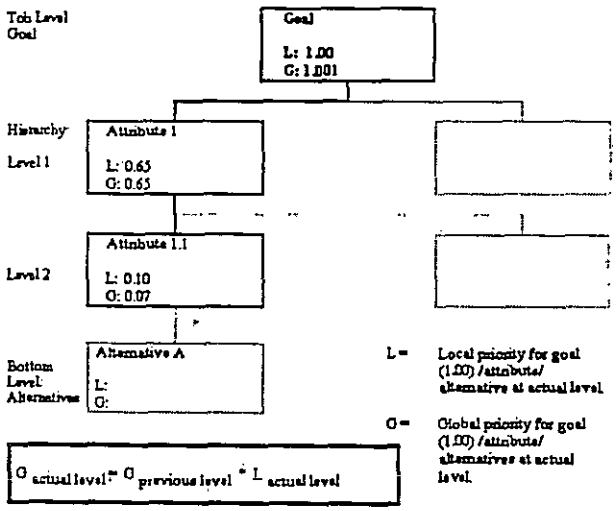
At European universities, AHP oriented OR courses generally follow the aforementioned steps (12).

Technically, AHP employs a method of **multi-paired comparisons of attributes** to rank order alternative solutions to a uni-objective problem.

The **basic structure of an AHP problem** can be clearly represented by an inverted **tree**. The **top level** contains only one element which reflects the overall **objective** to be attained. The **lower level** comprises the logically structured **attributes** to be compared in view of the preceding anchor element. The (optional) **bottom level** shows the **alternative solutions** to be considered in the AHP evaluation process.

The **evaluation** of these alternatives has to be based on the previously determined priority weights of the anchor elements according to the muliplication rule shown in Table 1.

Table 1. AHP Evaluation Tree



The determination of the **local weights** of the attributes at each level of the hierarchy has to follow the steps indicated in Table 2. Table 3 shows a numeric example of this AHP specific evaluation process; it relates to a CIM project which has to be evaluated on the basis of four main attributes.

Table 2. AHP Attribute Evaluation: Local weights

Attribute weights for pairwise comparisons	
Numerical scale	Verbal scale: Importance of row element over column element (column element over row element)
1 3 (1/3) 5 (1/5) 7/7) 9 (1/9)	equal moderate strong very strong extreme
2, 4, 6, 8 (1/2, 1/4, 1/6, 1/8)2	Intermediate values used for compromise between two adjacent judgements.

1. Attribute evaluation matrix: Original structure

$$A = \begin{bmatrix} a_{11}=1 & a_{12} & \cdots & a_{1n} \\ (a_{21}=1/a_{12}) & 1 & & a_{2n} \\ \vdots & \vdots & & \vdots \\ (a_{n1}=1/a_{1n}) & (a_{n2}) & & a_{nn}=1 \end{bmatrix}$$

2. Matrix A: Sum of columns

$$(1\ 1\ \ldots\ 1)A = \sum_i a_{i1} \ \ldots \ \sum_i a_{ij} \ \ldots \ \sum_i a_{in}$$

3. Normalized attribute evaluation matrix

$$B = \begin{bmatrix} a_{11}/\sum_i a_{i1} & \cdots & a_{1n}/\sum_i a_{in} \\ \vdots & & \\ a_{n1}/\sum_i a_{i1} & \cdots & a_{nn}/\sum_i a_{in} \end{bmatrix}$$

4. Matrix B: Sum of rows

$$B \begin{bmatrix} 1 \\ 1 \\ \vdots \\ 1 \end{bmatrix} = \begin{bmatrix} s_1 \\ s_2 \\ \vdots \\ s_n \end{bmatrix}$$

5. Attribute evaluation matrix: Eigenvector

$$\begin{vmatrix} s_1/n \\ s_2/n \\ \cdot \\ \cdot \\ \cdot \\ s_n/n \end{vmatrix} = \begin{vmatrix} w_1 \\ w_2 \\ \cdot \\ \cdot \\ \cdot \\ w_n \end{vmatrix}$$

6. Attribute evaluation matrix: Largest eigenvalue

$$A = \begin{vmatrix} w_1 \\ w_2 \\ \cdot \\ \cdot \\ \cdot \\ w_n \end{vmatrix} = \begin{vmatrix} u_1 \\ u_2 \\ \cdot \\ \cdot \\ \cdot \\ u_n \end{vmatrix}, \quad \lambda_{max} = (1\ 1\ \ldots\ 1) \begin{vmatrix} u_1/w_1 \\ u_2/w_2 \\ \cdot \\ \cdot \\ \cdot \\ u_n/w_n \end{vmatrix} (1/n)$$

7. Attribute evaluation matrix: Consistency index
CI = $(\lambda_{max} - n)/(n - 1)$
8. Attribute evaluation matrix: Consistency ratio
CR = CI/R

R values

Number of attributs	2	3	4	5	6	7	8	9	10
R	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

Table 3. AHP Attribute Evaluation: Example

Main criteria	Attribute evaluation matrix A				Normalized matrix A				Sum of rows normalized matrix A	Eigenve k-tor
	A1	A2	A3	A4	A1	A2	A3	A4		
A1 Structure	1	8	4	5	0.635	0.533	0.533	0.741	2.442	0.610
A2 Process	(0.125)	1	0.500	0.250	0.079	0.067	0.067	0.037	0.250	0.063
A3 Costs	(0.250)	(2)	1	0.500	0.159	0.133	0.133	0.074	0.499	0.125
A4 Risk	(0.200)	(4)	(2)	1	0.127	0.267	0.267	0.148	0.809	0.202
Sum of columns	1.575	15	7.500	6.750	1.000	1.000	1.000	1.000	4.000	1.000

For a full understanding of the AHP methodology a thorough **study of differently structured cases** is strongly recommended whereby the use of adequate AHP software programs seems practically indispensable.

12 AHP Software

The elaboration of AHP problems can be based on individual programs or, preferably, special AHP software packages.

Individual programs of the simplest type allow the determination of the local attribute weights within a **single**

hierarchy level. An automatic calculation of global weights for attribute and/or alternatives is not possible. Programs of this type are especially suitable for checking manual calculations; as a general rule they follow the practice of rounding to the last 2 or 3 digits.

Table 4 shows the basic structure of such a simple program; the results fully correspond to the ones shown in Table 3.

Table 4. AHP Program: Excel Spreadsheet

	A	B	C	D	E	F	G	H	I
1									
2		Factors/Attributes	A1	A2	A3	A4			
3	A1	Structure	1,000	8,000	4,000	5,000			
4	A2	Process	0,125	1,000	0,500	0,250			
5	A3	Costs	0,250	2,000	1,000	0,500			
6	A4	Risk	0,200	4,000	2,000	1,000			
7		sum of columns	1,575	15,000	7,500	6,750			
8									
9									
10		Factors/Attributes	A1	A2	A3	A4	sum of rows	weights	
11	A1	Structure	0,635	0,533	0,533	0,741	2,442	0,611	
12	A2	Process	0,079	0,067	0,067	0,037	0,250	0,062	
13	A3	Costs	0,159	0,133	0,133	0,074	0,499	0,125	
14	A4	Risk	0,127	0,267	0,267	0,148	0,808	0,202	
15		sum of columns	1,000	1,000	1,000	1,000	4,000	1,000	

	A	B	C	D	E	F	G	H
1								
2		Factors/Attributes	A1	A2	A3	A4		
3	A1	Structure	1,000					
4	A2	Process	=1/C4	1,000	0,500			
5	A3	Costs	=1/C5	=1/D5	1,000	0,500		
6	A4	Risk	=1/C6	=1/D6	=1/E6	1,000		
7		sum of columns	=SUM(C3:C6)	=SUM(D3:D6)	=SUM(E3:E6)	=SUM(F3:F6)		
8								
9								
10		Factors/Attributes	A1	A2	A3	A4	sum of rows	weights
11	A1	Structure	=C3/C$7	=D3/D$7	=E3/E$7	=F3/F$7	=SUM(C11:F11)	=G11/$G$15
12	A2	Process	=C4/C$7	=D4/D$7	=E4/E$7	=F4/F$7	=SUM(C12:F12)	=G12/$G$15
13	A3	Costs	=C5/C$7	=D5/D$7	=E5/E$7	=F5/F$7	=SUM(C13:F13)	=G13/$G$15
14	A4	Risk	=C6/C$7	=D6/D$7	=E6/E$7	=F6/F$7	=SUM(C14:F14)	=G14/$G$15
15		sum of columns	=SUM(C11:C14)	=SUM(D11:D14)	=SUM(E11:E14)	=SUM(F11:F14)	=SUM(G11:G14)	=SUM(H11:H14)

More **versatile programs** lead to a complete **AHP analysis**, together with an integral evaluation of the relevant alternatives. Such programs can, of course, also be used for stepwise attribute evaluations. The results shown in Table 5 have been generated by a powerful BASIC program which allows the creation of a multi-level AHP model (1). The final results differ from the ones given in Table 4. The differences are due to the fact that the NASA AHP BASIC program calculates the eigenvector by means of on intensity
incidence matrix of the type $A^2 = A \cdot A$. See Table 5 for details.

For complete AHP based project evaluations recurrence to **special software packages** is generally most advisable. This holds also for university based AHP courses.

Among the best known program packages - **Automan, Citerium 1.1, Expert Choice 7.1 and 8.0, Newtech Expert Choice** - Expert Choice 8.0 is the most versatile. It is also used at German universities and research centers.

Table 5. AHP Attribute Evaluation, Determination of the eigenvector by means of an intensity incidence matrix

Comparison Matrix at Level 1 with respect to

CIM

for the following Factors:

FACTOR 1 = Structure
FACTOR 2 = Process
FACTOR 3 = Costs
FACOTR 4 = Risk

	1	2	3	4
1	1.000	8.000	4.000	5.000
2	0.125	1.000	0.500	0.250
3	0.250	2.000	1.000	0.500
4	0.200	4.000	2.000	1.000

EIGENVECTOR = (0.624, 0.060, 0.120, 0.195)
Lambda Max = 4.107
C.I. = 0.036
C.R. = 0.040

Evaluation Matrix A * A = A^2

	A1	A2	A3	A4		A1	A2	A3	A4		A1	A2	A3	A4
A1	1.00	8.00	4.00	5.00	*	1.00	8.00	4.00	5.00	=	4.000	44.000	22.000	14.000
A2	0.125	1.00	0.50	0.25		0.125	1.00	0.50	0.25		0.425	4.000	2.000	1.375
A3	0.25	2.00	1.00	0.50		0.25	2.00	1.00	0.50		0.850	8.000	4.000	2.750
A4	0.20	4.00	2.00	1.00		0.20	4.00	2.00	1.00		1.400	13.600	6.800	4.000
									Sum of columns A^2		6.675	69.600	34.800	22.125

Normalized matrix A^2 | Sum of rows normalized A^2 | Eigenvector of A

	A1	A2	A3	A4		
A1	0.5993	0.6322	0.6322	0.6328	2.4965	0.6241
A2	0.0637	0.0575	0.0575	0.0621	0.2408	0.0602
A3	0.1273	0.1149	0.1149	0.1243	0.4814	0.1204
A4	0.2097	0.1954	0.1954	0.1808	0.7813	0.1953
Sum	1.0000	1.0000	1.0000	1.0000	4.0000	1.0000

Detailed descriptions of the program are available in a number of well-known textbooks (2,12), in addition to the official user's manuals.

For attribute and/or alternative evaluations Expert Choice uses the intensity incidence matrix method. Therefore, it is possible that the aforementioned differences between manually and automatically determined L values (local priorities) arise. But knowing the underlying reason might reassure student users and practitioners as well.

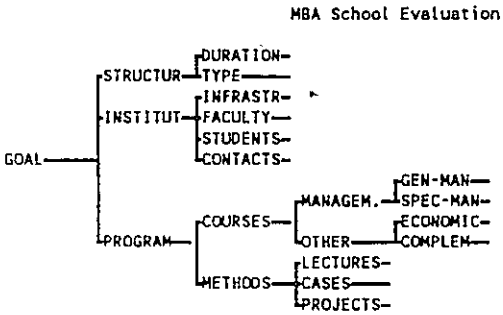
2 AHP Case Studies

The AHP methodology is not only of theoretical interest; it has also been used in widespread fields of human activities (9). The following discussion is restricted to AHP case studies in **Business Administration** and **Politics.**

21 Business Administration

Some of the most publicized German studies refer to AHP applications in the area of marketing and production. The techniques used correspond to similar American procedures and are not to be discussed in this context. The following practice report refers to the **ranking of European MBA schools.**

Table 6. MBA School Evaluation: Attribute structure



CASES	--- Case studies	COMPLEM	--- Complementary courses
CONTACTS	--- Contacts (universities, partnerships, private institutions)	DURATION	--- Duration (short/long)
ECONOMIC	--- Economics		
FACULTY	--- Faculty (professors, lecturers)	GEN-MAN	--- General Management
INFRASTR	--- Infrastructure (buildings, rooms, library, computer lab)	INSTITUT	--- Institution
LECTURES	--- Lecture and discussion	MANAGEM	--- Management (general/special management)
METHODS	--- Teaching methods	OTHER	--- Other courses (economics, statistics, ethics)
PROGRAM	--- Program	PROJECTS	--- Projects (consulting)
SPEC-MAN	--- Special Management	STRUCTUR	--- Structure of MBA program
STUDENTS	--- Students (nationality, age)	TYPE	--- American/European tradition

The study starts with a general **evaluation of European MBA schools** on the basis of the attribute structure shown in Table 6. The local priorities are established throughout the model by making paired comparisons of the attributes with respect to a common anchor which might be a precurrent attribute or the top item (goal) of the evaluation hierarchy. See Table 7 for the evaluation with respect to the top level (goal); similar calculations have to be made for the intermediate hierarchical levels.

Table 7. MBA School Evaluation: Sample attribute evaluation

JUDGMENTS WITH RESPECT TO
GOAL

	STRUCTUR	INSTITUT	PROGRAM
STRUCTUR		(4.0)	(5.0)
INSTITUT			(2.0)
PROGRAM			

Matrix entry indicates that ROW element is ___
1 EQUALLY 3 MODERATELY 5 STRONGLY 7 VERY STRONGLY 9 EXTREMELY
more IMPORTANT than COLUMN element unless enclosed in parenthesis.

PRIORITIES

STRUCTUR 0.097
INSTITUT 0.333
PROGRAM 0.570

INCONSISTENCY RATIO = 0.023.

The local priorities (attribute weights) are then successively multiplied along the anchoring lines in order to get the G values (Global priorities) at the lowest hierarchy level. See Table 8. The ranking of 20 European MBA schools is based on these G values; see Table 9 for an excerpt of the evaluation results which are based on the school offerings for 1994. It exemplifies also the actual use of the AHP specific **absolute measurement** techniques.

Table 8. MBA School Evaluation: Summary of the attribute weights (L and G)

MBA School Evaluation

GOAL		
L 1.000		
G 1.000		
STRUCTUR	**INSTITUT**	**PROGRAM**
L 0.097	L 0.333	L 0.570
G 0.097	G 0.333	G 0.570
DURATION	INFRASTR	COURSES
L 0.800	L 0.350	L 0.650
G 0.078	G 0.117	G 0.370
TYPE	FACULTY	METHODS
L 0.200	L 0.400	L 0.350
G 0.019	G 0.133	G 0.199
	STUDENTS	
	L 0.050	
	G 0.017	
	CONTACTS	
	L 0.200	
	G 0.067	

CONTACTS	---	Contacts (universities, partnerships, private institutions)
COURSES	---	Courses
DURATION	---	Duration (short, long)
FACULTY	---	Faculty (professors, lecturers)
INFRASTR	---	Infrastructure (buildings, rooms, library, computer lab)
INSTITUT	---	Institution
METHODS	---	Teaching methods
PROGRAM	---	Program
STRUCTUR	---	Structure of MBA program
STUDENTS	---	Students (nationality, age)
TYPE	---	American/ European tradition

L --- LOCAL PRIORITY: PRIORITY RELATIVE TO PARENT
G --- GLOBAL PRIORITY: PRIORITY RELATIVE TO GOAL

A complementary analysis can help potential MBA students to make a proper **school selection.** The relevant attribute structure is shown in Table 10. The evaluation would normally be restricted to about 2 or 3 preselected MBA schools. Therefore, it can be based on the standard AHP evaluation technique (**relative measurement**). See Table 11; the analysis refers to a hypothetical MBA applicant with strong reliance on the results of the general MBA school evaluation (G 0.434).

Table 9. MBA School Evaluation: Partial results

Alternatives	STRUCTUR DURATION .0779	STRUCTUR TYPE .0195	INSTITUT INFRASTR .1166	INSTITUT FACULTY .1332	INSTITUT STUDENTS .0167	INSTITUT CONTACTS .0666
1 E-3	0.300	0.700	0.800	0.700	0.700	0.700
2 NL-2	0.300	0.500	0.700	0.800	0.700	0.800
3 UK-5	0.700	0.500	0.900	0.700	0.700	0.800

Alternatives	PROGRAM COURSES MANAGEM. GEN-MAN .0888	PROGRAM COURSES MANAGEM. SPEC-MAN .2073	PROGRAM COURSES OTHER ECONOMIC .0148	PROGRAM COURSES OTHER COMPLEM .0592	PROGRAM METHODS LECTURES .0897	PROGRAM METHODS CASES .0797	PROGRAM METHODS PROJECTS .0299	Total
1 E-3	0.700	0.700	0.500	0.700	0.300	0.900	0.700	0.658
2 NL-2	0.300	0.700		0.700	0.500	0.700	0.900	0.627
3 UK-5	0.300	0.500		0.700	0.500	0.700	0.900	0.627

Alternatives	Total		
E-3	0.658	IESA	International Graduate School of Management, Barcelona
NL-2	0.627	RSM	Rotterdam School of Management, Rotterdam
UK-5	0.627	MBS	Manchester Business School, Manchester
E-2	0.617	IEDE	Institute for Executive Development, Madrid
F-1	0.603	INSEAD	The European Institute of Business Administration, Fontainebleau
CH-1	0.602	GBA	Graduate School of Business Administration, Zürich
CH-2	0.592	IMD	International Institute for Management Development, Lausanne
F-2	0.589	ISA	Institut Supérieur des Affaires, Jouy-en-Josas
UK-4	0.581	LBS	London Business School, London
B-1	0.565	KUL	Catholic University of Leuven, Leuven
NL-1	0.561	NBS	The Netherlands Business School, Breukelen
SF-1	0.558	HSEBA	Helsinki School of Economics and Business Administration, Helsinki
UK-2	0.555	CMS	Cranfield School of Management, Cranfield
F-3	0.546	EAP	Ecole Européenne des Affaires, Paris
I-1	0.537	SDA	Scuola di Direzione Aziendale, Milano
E-1	0.530	ESADE	Escuela Superior de Administración y Dirección de Empresas, Barcelona
E-4	0.507	MBS	Madrid Business School, Madrid
UK-6	0.506	WBS	Warwick Business School, Coventry
UK-3	0.422	HMC	Henley Management College, Henley-on-Thames
UK-1	0.281	AMC	Ashridge Management College, Berkhamsted

Table 10. MBA School Selection: Attribute structure

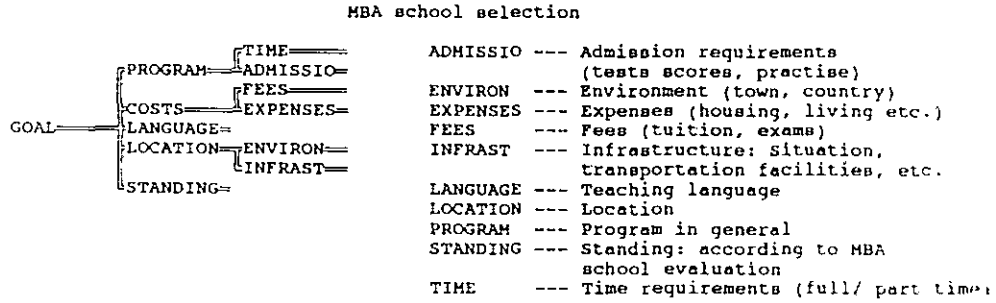


Table 12 shows the evaluation results on a single graph. Furthermore, a dynamic sensitivity analysis indicates that a heavier weighting of the cost factors would lead to a definite preference for the second MBA school.

Table 11. MBA School Selection: 3 Top schools

JUDGMENTS WITH RESPECT TO GOAL

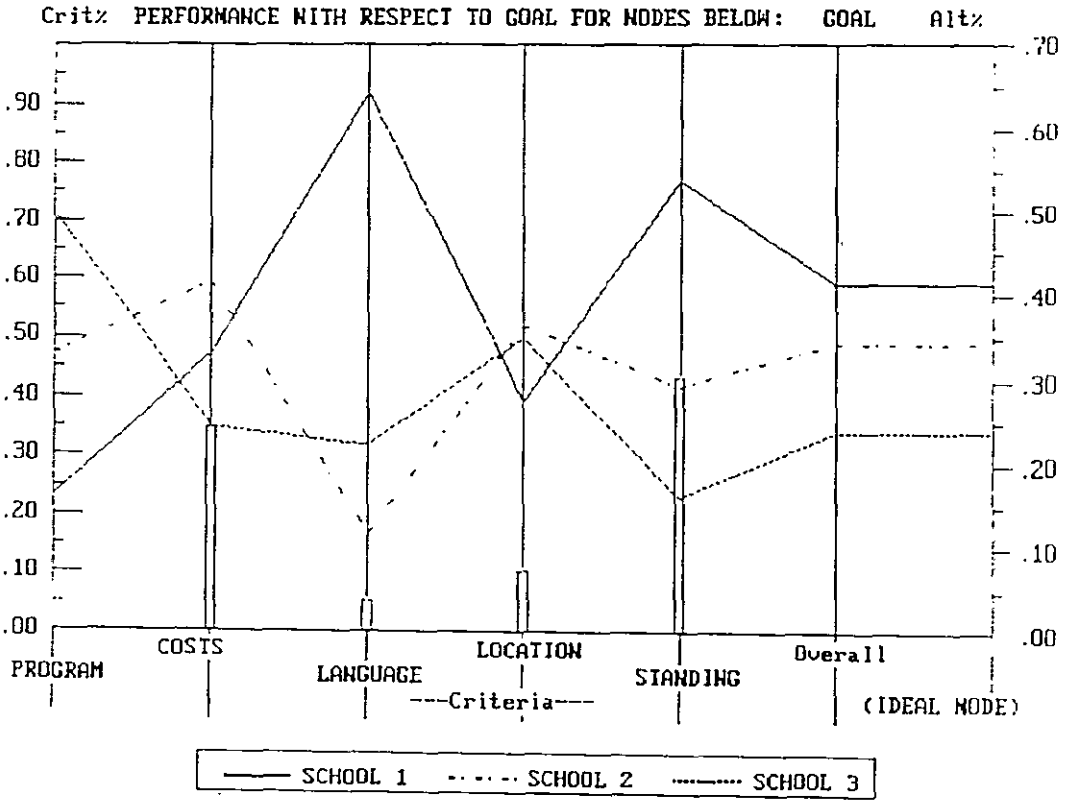
	PROGRAM	COSTS	LANGUAGE	LOCATION	STANDING
PROGRAM		(7.0)	2.0	(2.0)	(9.0)
COSTS			5.0	3.0	1.0
LANGUAGE				(2.0)	(7.0)
LOCATION					(5.0)
STANDING					

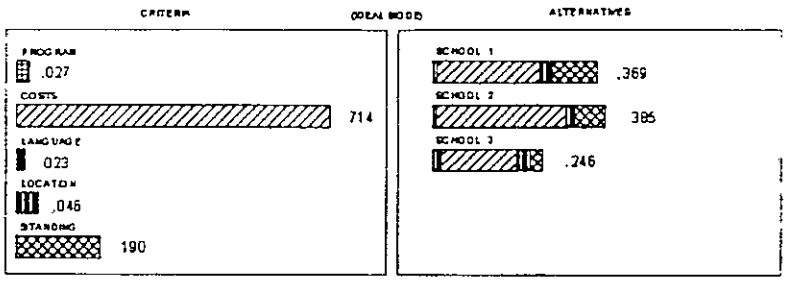
PRIORITIES

PROGRAM	0.062
COSTS	0.349
LANGUAGE	0.052
LOCATION	0.104
STANDING	0.434

INCONSISTENCY RATIO = 0.028.

Table 12. MBA School Selection: Complementary analysis





22 Politics

AHP analyses can - especially for educational purposes - be repeated under similar or slightly changed conditions. Of even greater importance are **follow-up studies** that refer to **real life situations.** Such analyses would allow an **appraisal** of **the original expert judgements.**

Table 13. US Presidential Elections: Original study

US Presidential Election 1992

GOAL	PERSON	POTENT	ACTIVITY	DOMESTIC	FOREIGN	SUPPORT
L 1.000	L 0.047	L 0.154	L 0.061	L 0.174	L 0.316	L 0.248
G 1.000	G 0.047	G 0.154	G 0.061	G 0.174	G 0.316	G 0.248
	APPEAR	LEADER	EXTRAGO	EMPLOYM	ECONOMY	CAMPAIGN
	L 0.431	L 0.335	L 0.054	L 0.153	L 0.521	L 0.081
	G 0.020	G 0.052	G 0.003	G 0.027	G 0.165	G 0.020
	AGE	NEGOTIAT	PARLIAME	FINANCE	SECURITY	PARTY
	L 0.156	L 0.503	L 0.357	L 0.043	L 0.115	L 0.061
	G 0.007	G 0.077	G 0.022	G 0.007	G 0.036	G 0.015
	HEALTH	STABILIT	EXECUT	TAXES	DEVELOP	VIZE-PR
	L 0.366	L 0.106	L 0.589	L 0.345	L 0.187	L 0.241
	G 0.017	G 0.016	G 0.036	G 0.060	G 0.059	G 0.060
	CHARM	INTEGRIT		AGRAR	INTERNAT	MEDIA
	L 0.048	L 0.055		L 0.056	L 0.177	L 0.255
	G 0.002	G 0.008		G 0.010	G 0.056	G 0.063
				ENERGY		UNIONS
				L 0.164		L 0.170
				G 0.029		G 0.042
				SOCIAL		GROUPS
				L 0.196		L 0.191
				G 0.034		G 0.047
				TECHNOL		
				L 0.042		
				G 0.007		

ACTIVITY	--- Activities	AGE	--- Age
AGRAR	--- Agricultural policy	APPEAR	--- General appearance
CAMPAIGN	--- Presidential campaign	CHARM	--- Charm/carisma
DEVELOP	--- Development policy	DOMESTIC	--- Domestic policy
ECONOMY	-- Economic policy (GATT, NAFTA	EMPLOYM	--- Employment policy
ENERGY	--- Energy policy	EXECUT	--- Prior experience as a member of the executive: governor/president
EXTRAGO	--- Extrogovernmental activities: studies, military service	FINANCE	--- Financial policy (inflation/debts)
FOREIGN	--- Foreign policy	GROUPS	--- Ethnic / religious groups
HEALTH	--- Health	INTEGRIT	--- Integrity/credibility
INTERNAT	--- Internat. policy (UNO, Security Council	LEADER	--- Leadership
MEDIA	--- Media support	NEGOTIAT	--- Negotiating abilities
PARLIAME	--- Parliamentary activities: member/relations to parliament	PARTY	--- Party
PERSON	--- Personality (G. Bush, B. Clinton)	POTENT	--- Potential
SECURITY	--- Security policy	SOCIAL	--- Social policy (social security)
STABILIT	--- Stability/constancy	SUPPORT	--- Support (endorsement)
TAXES	--- Fiscal policy (taxes)	TECHNOL	--- Technological policy
UNIONS	--- Labor unions	VIZE-PR	--- Incoming vice-president (D. Quayle / A. Gore)

OVERALL INCONSISTENCY INDEX = 0.02

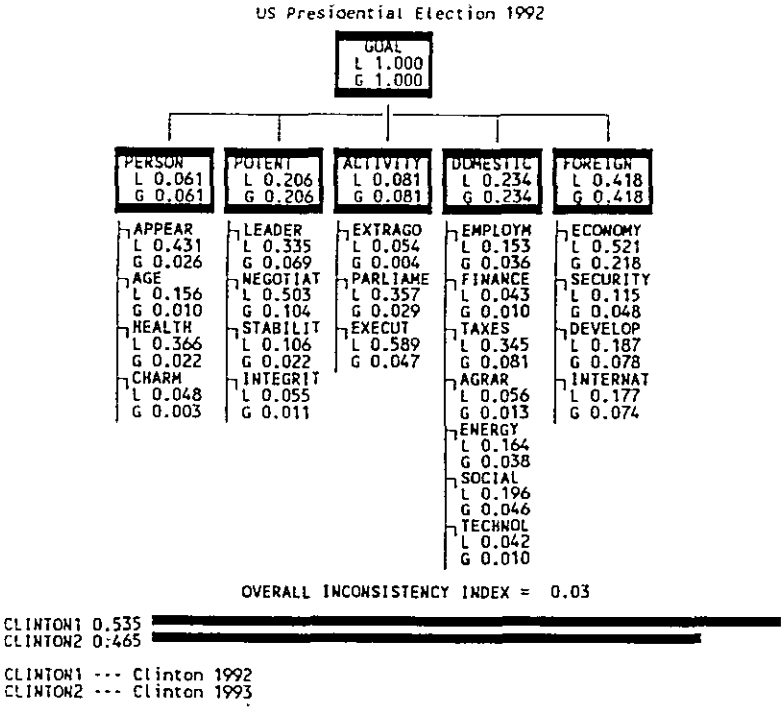
A typical case study of the latter kind relates to the American presidential elections of 1992. A short summary of the **original study** (prepared in September 1992 by the author) is shown in Table 13. The study was correct in predicting the actual outcome of the election in November 1992.

An additional analysis, now comparing the expected and actual performance of President Clinton (as of November 1993) has produced the results shown in Table 14. The factors at the first attribute level are generally higher by about 25 %; this is due to a proportional reallocation of the now obsolute SUPPORT weights (0.248).

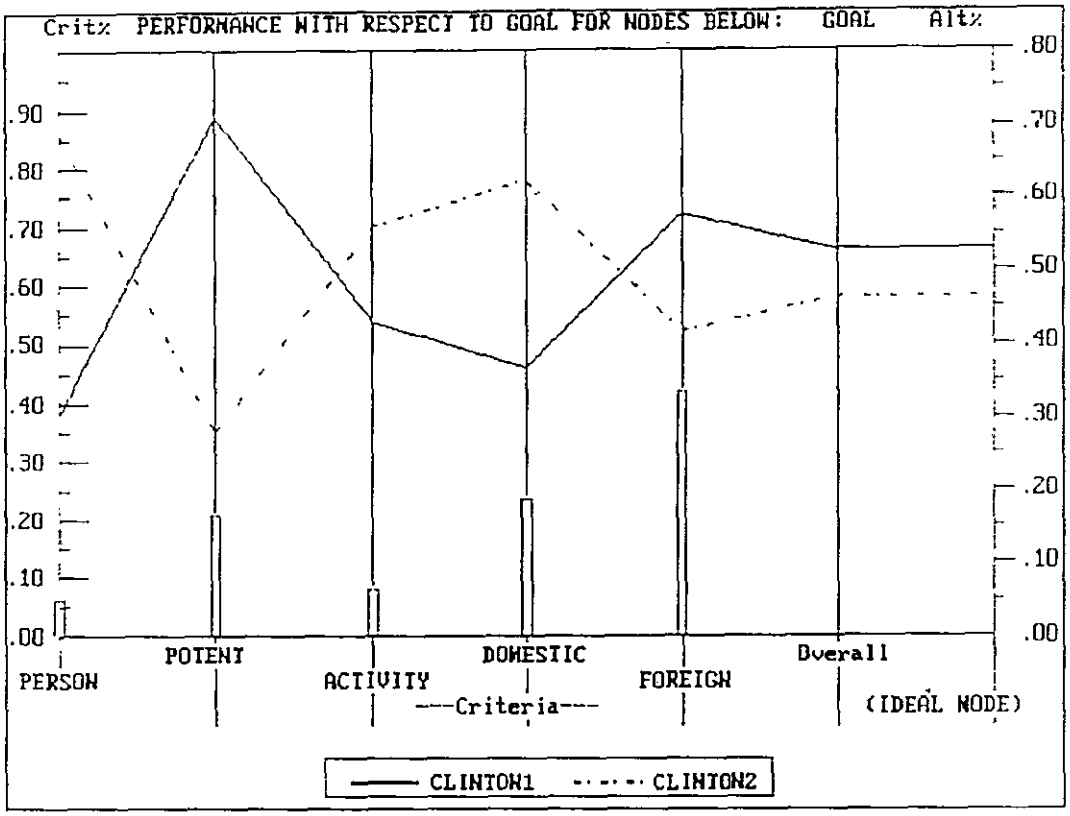
The results of the follow-up study show some significant deviations in the evaluation of Clinton-1 (pre election) and Clinton-2 (post election). These variations are mainly due to the President's performance in the field of foreign policy.

The current political situation in Africa (Somalia) and Europe (ex-Jugoslawia) might even call for a **revision of the original attribute evaluation**, combined with a periodic (e.g. monthly) **ranking** of the President's performance. Analyses of this type (absolute measurement) can easily be performed by the aid of Expert Choice 8.0.

Table 14. US Presidential Elections: Follow-up study



CLINTON1 --- Clinton 1992
CLINTON2 --- Clinton 1993



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