International Student Conference on Applied Mathematics and Informatics
2012

Selection of Business Intelligence Systems by AHP and Fuzzy AHP

An Empirical Study from Ankara Production Sector

Avnican ÇARMIKLI

Emir Hüseyin ÖZDER

ATILIM UNIVERSITY
DEPARTMENT OF INDUSTRIAL ENGINEERING

Overview of the Presentation

- Decision Support and Business Intelligence Systems
- Study Outline and Method
- Survey on Business Intelligence Applications
- Selection of Business Intelligence Systems
- Analytic Hierarchy Process (AHP)
- Fuzzy AHP
- Conclusion

Decision Support Systems

- Computer based information systems.
- Provide information support to managers and business professionals during the decision making processes.
- Business Intelligence (BI) systems are the most well known type of Decision Support Systems.

Business Intelligence Systems

- BI systems use analytical models, specialized databases, decision makers' own insights and judgments, and interactive computer-based modeling process to support business decisions.
- BI systems capable to perform data mining, statistical analysis, what-if scenarios and analytical processing of data so as to incorporate decision making and to enhance representation of knowledge.

Study Outline and Method

- The survey on business intelligence applications was conducted among 82 Turkish companies in Ankara Production sector in order to demonstrate

➢ Perceived Business values from BI systems.

➢ Effectiveness of BI systems on decision making support.

➢ Necessity for the use of BI systems.

Study Outline and Method

- In the second stage of the project, case study was carried out to select the most suitable BI software for the companies in Ankara Production sector.
- In the selection methodology, an analytic modeling approach such as Analytic Hierarchy Process (AHP) and Fuzzy AHP methods have been used for evaluating BI software alternatives on the basis of selection criteria.

Survey on Business Intelligence Applications

- The survey was conducted with the application of questionnaires to 82 Turkish companies from different business segments in production sector that implement BI tools for decision support.
- The questions in the questionnaire consist of 3 categories,

  1: Visions, objectives and strategies

  2: Business values from BI systems

  3: Decision making support

Survey on Business Intelligence Applications

The respondents' business segments

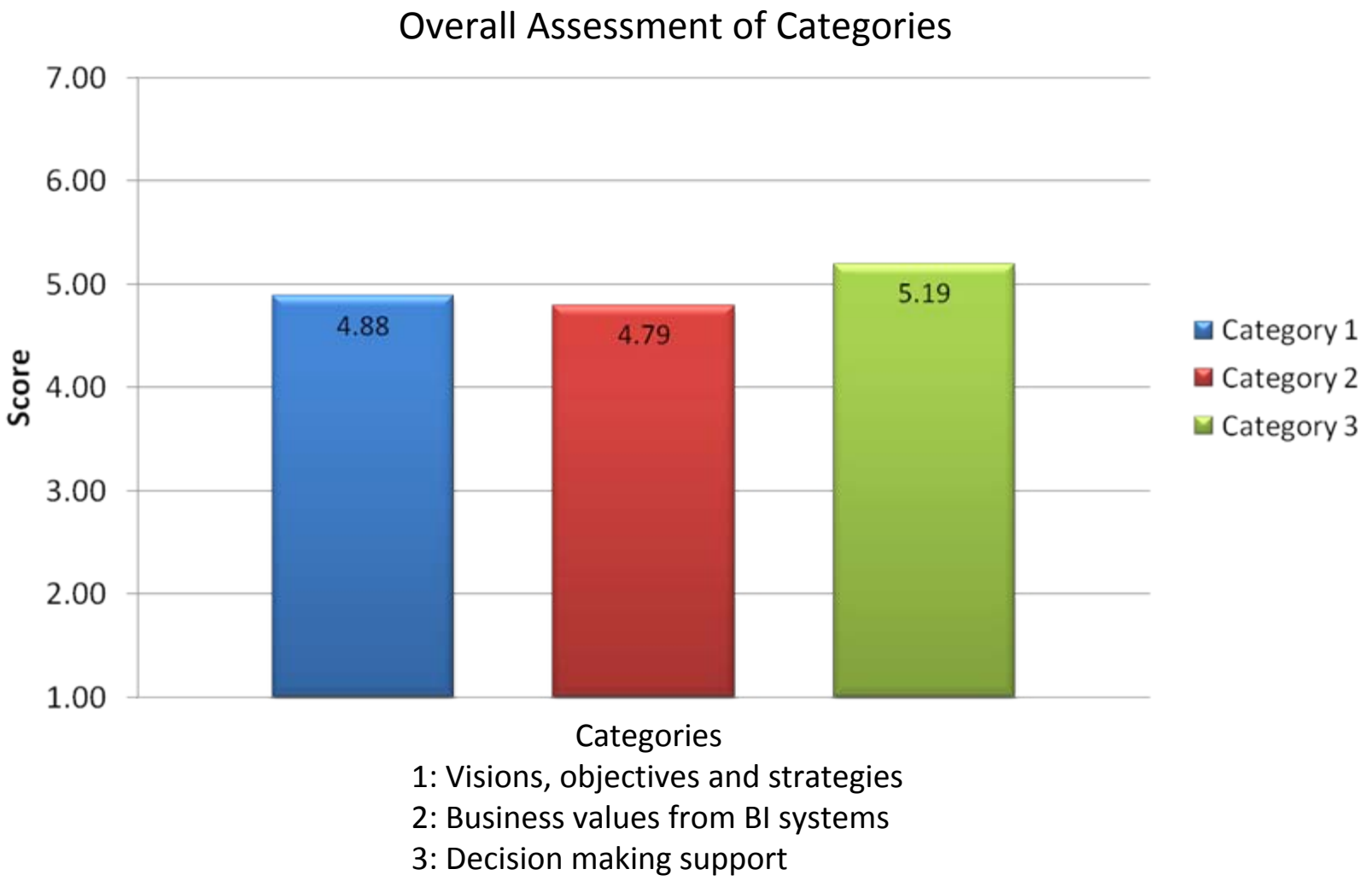
Business Segments	Count
Machinery and Metal Forming	21
Electronics	14
Real Estate and Construction	10
Defense	9
Home Appliances	7
Pharmaceutical and Healthcare	5
Food and Catering	4
Energy	4
Textile	3
Others	5
TOTAL	***82***

Survey on Business Intelligence Applications

Respondents' role (Some have more than one role)

Role	Count
Company Owner	13
CEO	9
CIO	6
CFO	4
Other Management	15
Head of Business Segment	12
IT Management	11
Supervisor	5
Engineer	6
System Developer	7
Others	3
TOTAL	***91***

Survey on Business Intelligence Applications



Selection of Business Intelligence Systems

- This study brings a multi criteria decision making approach to select the BI vendor among possible alternatives with respect to specific criteria.
- The alternatives were determined as **SAP** and **Microsoft** since they are most qualified and well known Business intelligence vendors.

Selection of Business Intelligence Systems

- The specified decision criteria for the selection of BI software:
  - Analytical Modeling & Processing (C_1)
  - Data Visualization & Graphical Support (C_2)
  - User Interface (C_3)
  - Technical Guidance & Support (C_4)
  - Cost (C_5)

Analytic Hierarchy Process (AHP)

- The AHP enables the decision-makers to structure a complex problem under multiple criteria environment.
- With AHP, the decision maker selects the alternative that best meets his decision criteria developing a numerical score to rank each decision alternative based on how well each alternative meets them.

Analytic Hierarchy Process (AHP)

- **Methodology;**
- ***Obtaining Weights for Each Decision Criteria***
- **Step 1:** Ranking each criteria in the Pair-wise Comparison Matrix
- **Step 2:** Normalize each column to get a new judgment matrix A ' by dividing Each Value to The Column Total.
- **Step 3:** Take average of each row of normalized matrix A' to assign the importance levels (weights of criteria) by dividing the sum of rows by the number of criteria.
- ***Scoring Alternatives as per Each Decision Criteria***
- Pair-wise comparison matrix for alternatives should be constructed for each decision criteria
- ***Obtaining Overall Score of Each Alternative***
- Matrix multiplication will be performed between the alternative ranking matrix and decision criteria weights matrix

Analytic Hierarchy Process (AHP)

- **Consistency Test:** The additional step in AHP analysis is checking for the consistency of the decision maker's comparisons. We can use the following equation to calculate the consistency index (CI):

$$CI = \frac{\left\{ \frac{1}{n} \sum_{i=1}^{i=n} \frac{ith\ entry\ in\ AW}{ith\ entry\ in\ W} \right\} - n}{n-1}$$

- Where "AW" equals the matrix multiplication of Pair-wise comparison matrix A and the normalized weight matrix W.
- The values of Random Index (RI) are shown in below table.

Size of matrix	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

- The comparison matrix will be considered to be consistent if

$$CR = \frac{CI}{RI} < 0.10$$

Analytic Hierarchy Process (AHP)

The Pair Wise Comparison Matrix According to The Criteria					
	C1	**C2**	**C3**	**C4**	**C5**
C1	1,000	3,000	5,000	7,000	5,000
C2	0,333	1,000	1,000	5,000	3,000
C3	0,200	1,000	1,000	3,000	1,000
C4	0,143	0,200	0,333	1,000	0,333
C5	0,200	0,333	1,000	3,000	1,000
Column Total	**1,876**	**5,533**	**8,333**	**19,000**	**10,333**

Division of Each Value to The Column Total					
	C1	**C2**	**C3**	**C4**	**C5**
C1	0,533	0,542	0,600	0,368	0,484
C2	0,178	0,181	0,120	0,263	0,290
C3	0,107	0,181	0,120	0,158	0,097
C4	0,076	0,036	0,040	0,053	0,032
C5	0,107	0,060	0,120	0,158	0,097

Analytic Hierarchy Process (AHP)

The Average Values						
	C1	**C2**	**C3**	**C4**	**C5**	**Importance Level**
C1	0,533	0,542	0,600	0,368	0,484	0,505
C2	0,178	0,181	0,120	0,263	0,290	0,206
C3	0,107	0,181	0,120	0,158	0,097	0,132
C4	0,076	0,036	0,040	0,053	0,032	0,047
C5	0,107	0,060	0,120	0,158	0,097	0,108

Importance Level	
Analytical Modeling & Processing	**0,505**
Data Visualization & Graphical Support	**0,206**
User Interface	**0,132**
Technical Guidance & Support	**0,047**
Cost	**0,108**

Analytic Hierarchy Process (AHP)

Consistency Test of the Comparison Matrix

Consistency Analysis	
Step 1	**$A*W^t$**
	2,660
	1,069
	0,690
	0,241
	0,553
Step2	**1/n*[Sum of (ith entry of (A*Wt)/Wt)]**
	5,170
Step3	**Compute CI [(Step2 result)-n] / (n-1)**
	0,042
Step 4	RI (Random Index) for n=5 equals 1,12
	CI/RI
	0,038
if CI/RI < 0.10 , the comparison matrix is consistent	
CONSISTENT	

Analytic Hierarchy Process (AHP)

Scoring Alternatives as per Each Decision Criteria

Analytical Modeling & Processing (C1)	SAP	MS.
SAP	1,000	7,000
MICROSOFT	0,143	1,000
Column Total	1,143	8,000

Analytical Modeling & Processing	SAP	MS.	Score
SAP	0,875	0,875	0,875
MICROSOFT	0,125	0,125	0,125
Column Total	1,000	1,000	

Data Visualization & G.S. (C2)	SAP	MS.
SAP	1,000	3,000
MICROSOFT	0,333	1,000
Column Total	1,333	4,000

Data Visualization & G.S.	SAP	MS.	Score
SAP	0,750	0,750	0,750
MICROSOFT	0,250	0,250	0,250
Column Total	1,000	1,000	

User Interface (C3)	SAP	MS.
SAP	1,000	0,333
MICROSOFT	3,000	1,000
Column Total	4,000	1,333

User Interface	SAP	MS.	Score
SAP	0,250	0,250	0,250
MICROSOFT	0,750	0,750	0,750
Column Total	1,000	1,000	

Analytic Hierarchy Process (AHP)

Scoring Alternatives as per Each Decision Criteria

Technical Guidance & Support (C4)	SAP	MS.
SAP	1,000	3,000
MICROSOFT	0,333	1,000
Column Total	1,333	4,000

Technical Guidance & Support	SAP	MS.	Score
SAP	0,750	0,750	0,750
MICROSOFT	0,250	0,250	0,250
Column Total	1,000	1,000	

Cost (C5)	SAP	MS.
SAP	1,000	0,200
MICROSOFT	5,000	1,000
Column Total	6,000	1,200

Cost	SAP	MS.	Score
SAP	0,167	0,167	0,167
MICROSOFT	0,833	0,833	0,833
Column Total	1,000	1,000	

Scores of Alternatives					
	Analytical Modeling & Processing	**Data Visualization & Graphical Support**	**User Interface**	**Technical Guidance & Support**	**Cost**
SAP	0,875	0,750	0,250	0,750	0,167
MS.	0,125	0,250	0,750	0,250	0,833

Analytic Hierarchy Process (AHP)

Calculating Overall Score of Each Alternative

Scores of Alternatives					
	C1	**C2**	**C3**	**C4**	**C5**
SAP	0,875	0,750	0,250	0,750	0,167
MS.	0,125	0,250	0,750	0,250	0,833

X

Importance Levels of Criteria	
C1	0,505
C2	0,206
C3	0,132
C4	0,047
C5	0,108

Overall Scores	
SAP	**0,684**
MICROSOFT	**0,316**

Fuzzy AHP

- In complex systems, the experiences and judgments of humans are represented by linguistic and vague patterns.
- Therefore, a much better representation of this linguistics can be developed as quantitative data; this type of data set is then refined by the evaluation methods of fuzzy set theory.
- The fuzzy AHP technique can be viewed as an advanced analytical method developed from the traditional AHP.

Fuzzy AHP

- Fuzzy AHP also has pair wise comparison matrix like classical AHP approach. However, triangle fuzzy numbers instead of constant numbers are used to judge criteria in the comparison matrix. Accordingly, assignment of Triangular Fuzzy sets Scale are represented as follows,

Linguistic scale	Explanation	TFN	Inverse TFN
Equal Importance	Two activities contribute equally to the objective	(1,1,1)	(1,1,1)
Moderate Importance	Experience and judgment slightly favor one activity over another	(1,3,5)	(1/5,1/3,1)
Strong Importance	Experience and judgment strongly favor one activity over another	(3,5,7)	(1/7,1/5,1/3)
Very Strong Importance	An activity is favored very strongly over another, its dominance	(5,7,9)	(1/9,1/7,1/5)

Fuzzy AHP

- According to the responses on the question form, the corresponding triangular fuzzy values for the linguistic variables are placed and for a particular level on the hierarchy the pair wise comparison matrix is constructed.
- Sub totals are calculated for each row of the matrix and new *(l, m, u)* set is obtained, then in order to find the overall triangular fuzzy values for each criterion, *li/Σli, mi/Σmi, ui/Σui,(i=1,2,..., n)* values are found and used as the latest $Mi(l_i, m_i, u_i)$ set for criterion *Mi* in the rest of the process.

Fuzzy AHP

- The basic operations to be applied throughout FAHP method are represented as:

$$\tilde{M}_1 \oplus \tilde{M}_2 = (l_1 + l_2, m_1 + m_2, u_1 + u_2)$$

$$\tilde{M}_1 \otimes \tilde{M}_2 = (l_1 l_2, m_1 m_2, u_1 u_2)$$

$$\tilde{M}_1^{-1} = \left(\frac{1}{u_1}, \frac{1}{m_1}, \frac{1}{l_1}\right)$$

- The steps of Chang's analysis can be given as follows:
- **Step 1:** The value of fuzzy synthetic extent with respect to the i th object is defined as

$$S_i = \sum_{j=1}^{m} M_{gi}^{j} \otimes \left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{gi}^{j} \right]^{-1}$$

Fuzzy AHP

- **Step 2:** As $M_1=(l_1,m_1,u_1)$ and $M_2=(l_2,m_2,u_2)$ are two triangular fuzzy numbers, i.e. the degree of possibility of $S_2=(l_2,m_2,u_2)$ $S_1=(l_1,m_1,u_1)$ can be equivalently expressed as follows:

$$V(M_2 \geq M_1) = \begin{cases} 1, & \text{if } m_2 \geq m_1, \\ 0, & \text{if } l_1 \geq u_2, \\ \dfrac{l_1 - u_2}{(m_2 - u_2) - (m_1 - l_1)} & \text{otherwise} \end{cases}$$

Fuzzy AHP

- **Step 3:** Assume that $d(A_i) = \min V(S_i \; S_k)$ for $k = 1,2,....,n; k \neq i$. Then the weight vector is given by $W' = (d'(A_{1|}), d'(A_2), ..., d'(A_n))^T$ where A_i=(i=1,2,...n) are n elements.
- **Step 4:** Via normalization, the normalized weight vectors are $W = (d(A_1), d(A_2), ..., d(A_n))^T$ where W is a non-fuzzy number.

Fuzzy AHP

- **Obtaining Weights for Each Decision Criteria**

Step 1:

The Pair Wise Comparison Matrix According to The Criteria														
	C1			C2			C3			C4			C5		
C1	1,00	1,00	1,00	1,00	3,00	5,00	3,00	5,00	7,00	5,00	7,00	9,00	3,00	5,00	7,00
C2	0,20	0,33	1,00	1,00	1,00	1,00	1,00	1,00	1,00	3,00	5,00	7,00	1,00	3,00	5,00
C3	0,14	0,20	0,33	1,00	1,00	1,00	1,00	1,00	1,00	1,00	3,00	5,00	1,00	1,00	1,00
C4	0,11	0,14	0,20	0,14	0,20	0,33	0,20	0,33	1,00	1,00	1,00	1,00	0,20	0,33	1,00
C5	0,14	0,20	0,33	0,20	0,33	1,00	1,00	1,00	1,00	1,00	3,00	5,00	1,00	1,00	1,00

Intermediate operations to calculate Synthesis Values

A1	13,00	21,00	29,00
A2	6,20	10,33	15,00
A3	4,14	6,20	8,33
A4	1,65	2,01	3,53
A5	3,34	5,53	8,33

S_5= 3,34*0,02; 5,53*0,02;8,33*0,04

Fuzzy Set Column Sum		
64,20	45,08	28,34

Reciprocal of Fuzzy Set Column Sum		
0,02	0,02	0,04

Fuzzy AHP

- **Synthesis Values**

S1			S2			S3			S4			S5		
l	m	u	l	m	u	l	m	u	l	m	u	l	m	u
0,20	0,47	1,02	0,10	0,23	0,53	0,06	0,14	0,29	0,03	0,04	0,12	0,05	0,12	0,29

Step 2

V(S1>=S2)	1,00
V(S1>=S3)	1,00
V(S1>=S4)	1,00
V(S1>=S5)	1,00

V(S2>=S1)	0,58
V(S2>=S3)	1,00
V(S2>=S4)	1,00
V(S2>=S5)	1,00

V(S3>=S1)	0,22
V(S3>=S2)	0,68
V(S3>=S4)	1,00
V(S3>=S5)	1,00

V(S4>=S1)	0,00
V(S4>=S2)	0,13
V(S4>=S3)	0,39
V(S4>=S5)	0,48

V(S5>=S1)	0,21
V(S5>=S2)	0,65
V(S5>=S3)	0,94
V(S5>=S4)	1,00

Step 3

D(A1)	**1,00**

D(A2)	**0,58**

D(A3)	**0,22**

D(A4)	**0,00**

D(A5)	**0,21**

Fuzzy AHP

Step 4: Importance Weights Vector

	C1	C2	C3	C4	C5
W'	1,00	0,58	0,22	0,00	0,21

- **Normalization**

		C1	C2	C3	C4	C5
Overall weights	W	0,50	0,29	0,11	0,00	0,10

Fuzzy AHP

- **Scoring Alternatives as per Each Decision Criteria**
- **C1: Analytical Modeling & Processing**

C1	SAP			MICROSOFT		
SAP	1,00	1,00	1,00	5,00	7,00	9,00
MICROSOFT	0,11	0,14	0,20	1,00	1,00	1,00

Intermediate operations to calculate Synthesis Values

A1	6,00	8,00	10,00
A2	1,11	1,14	1,20

Fuzzy Set Column Sum		
11,20	9,14	7,11

Reciprocal of Fuzzy Set Column Sum		
0,09	0,11	0,14

Synthesis Values	S1			S2		
	l	m	u	l	m	u
	0,54	0,88	1,41	0,10	0,13	0,17

Fuzzy AHP

- **Scoring Alternatives as per Each Decision Criteria**

Synthesis Values	S1			S2		
	l	m	u	l	m	u
	0,54	0,88	1,41	0,10	0,13	0,17

V(S1>=S2)	1,00	V(S2>=S1)	0,00

Imp. Weights				
	D(A1)	**1,00**	**D(A2)**	**0,00**

Importance Weights Vector			
	W'	1,00	0,00

Normalization

	C1	SAP	MICROSOFT
Overall weights	**W**	**1,00**	**0,00**

Fuzzy AHP

- **Scoring Alternatives as per Each Decision Criteria**
- **C2: Data Visualization & Graphical Support**

C2	SAP			MICROSOFT		
SAP	1,00	1,00	1,00	1,00	3,00	5,00
MICROSOFT	0,20	0,33	1,00	1,00	1,00	1,00

Intermediate operations to calculate Synthesis Values

A1	2,00	4,00	6,00
A2	1,20	1,33	2,00

Fuzzy Set Column Sum		
8,00	5,33	3,20

Reciprocal of Fuzzy Set Column Sum		
0,13	0,19	0,31

	S1			S2		
	l	m	u	l	m	u
Synthesis Values	0,25	0,75	1,88	0,15	0,25	0,63

Fuzzy AHP

- **Scoring Alternatives as per Each Decision Criteria**

Synthesis Values	S1			S2		
	l	**m**	**u**	**l**	**m**	**u**
	0,25	0,75	1,88	0,15	0,25	0,63

	V(S1>=S2)	1,00	V(S2>=S1)	0,43
Imp. Weights	**D(A1)**	**1,00**	**D(A2)**	**0,43**

Importance Weights Vector	**W'**	1,00	0,43

Normalization	**C2**	**SAP**	**MICROSOFT**
Overall weights	**W**	**0,70**	**0,30**

Fuzzy AHP

- Calculation of Overall scores

	C1	C2	C3	C4	C5
SAP	1,00	0,70	0,30	0,70	0,00
MICROSOFT	0,00	0,30	0,70	0,30	1,00

X

Importance Levels of Criteria	
C1	0,50
C2	0,29
C3	0,11
C4	0,00
C5	0,10

Overall Scores	
SAP	0,73
MICROSOFT	0,27

Conclusion

- By taking into consideration of the facts and findings of the Survey on Business Intelligence Applications,
- Most of the respondents agree that BI systems support meeting organizational goals and strategies.
- BI systems support core business process and provide relevant information to different business divisions as per their needs.
- BI systems have considerable impact on attaining more effective decision making. It implies that BI systems are utilized well in the companies implementing BI tools to incorporate decision making.

Conclusion

- As a result of case study, The best alternative for BI systems was selected **SAP** by means of AHP and Fuzzy AHP analysis with the overall scores of
- (68% SAP), (32% Microsoft) from AHP analysis.
- (73% SAP), (27% Microsoft) from FAHP analysis.

Conclusion

- There are some major differences between AHP and FAHP as represented below,

Classical AHP	Fuzzy AHP
Assessment with Deterministic Values	Assessment with Linguistic and Fuzzy Variables
Applicable for Consistency Test	Not applicable for Consistency Test
Preferable when Certain information available for judgement	Preferable when Uncertainty and vaugeness exist in the jugdment process
In the result of pairwise comparisons, the importance weights of criterion can not be obtained as “Zero”	The importance weights of criterion can be obtained as “Zero” since Fuzzy AHP totally neglects the criterion which is less important than the others

References

- Riabacke, A., Larsson, A. and Danielson, M.: Business Intelligence as Decision Support in Business Processes: An Emprical Investigation. (2011). p. 384-391.
- Ballı, S. and Korukoğlu, S.: Operating System Selection Using Fuzzy Ahp And Topsis Methods. Mathematical and Computational Applications, Vol. 14, No. 2. (2009). p. 119-130.
- Ozdagoglu, A. and Ozdagoglu, G. Comparison Of Ahp And Fuzzy Ahp For The Multicriteria Decision Making Processes With Linguistic Evaluations. (2007). p. 65-75.
- Cebeci, U.: Fuzzy AHP-based decision support system for selecting ERP systems in textile industry by using balanced scorecard. Expert Systems with Applications, No. 36 (2009). p. 8900-8909.
- Kong, F. and LIU, H.: Applying Fuzzy Analytic Hierarchy Process To Evaluate Success Factors Of E-Commerce. International Journal of Information and Systems Sciences, Vol 1.(2005). p. 406-412.

Thanks for Listening