ΔΙΑΧΕΙΡΙΣΗ ΕΡΓΩΝ ΠΛΗΡΟΦΟΡΙΚΗΣ

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Requirements prioritazation

Περιεχόμενα

- Εισαγωγή
- Βασικές έννοιες
- Μέθοδοι προτεραιοποίησης
- Σύγκριση μεθόδων

Το πρόβλημα

- There are usually more requirements than you can implement given stakeholder`s time and resource constraints… [Kar97],

- … Από την άλλη πλευρά, τα συστήματα έχουν λειτουργίες που ποτέ δεν χρησιμοποιούντα από τους χρήστες
- Στόχος είναι να υλοποιήσουμε μόνο τις χρήσιμες απαιτήσεις. Το αποτέλεσμα είναι:
  - Χρόνος ανάπτυξης μειώνεται
  - Το κόστος μειώνεται
  - Το προϊόν έχει λιγότερα σφάλματα και
  - Είναι πιο απλό στη χρήση

  ”How to select a subset of the customers´ requirements and still produce a system that meets their needs?”
-

Large amount of the software functions are ”rarely” (19%) or ”never used” (45%) [Moi00]

Βασική αρχή της προτεραιοποίησης

- ”Prioritization means balancing the business benefit of each requirement against its cost and any implications it has for the architechtural foundation and future evolution of the product ” [Wie99]

”If the customers do not differentiate their requirements by importance and urgency, project managers must make these decisions on their own.” [Wie99]

”Most software organisations carry out this selection process informally and quite frequently produce systems that developers, customers and users view as suboptimal.” [Kar97]

Μέθοδος προτεραιοποίησης με κατηγορίες (1/2)

- Μέθοδος
  - Ομαδοποιούμε τις απαιτήσεις σε κατηγορίες
  - Συνήθως σε τρία επίπεδα (e.g. Απολύτως απαραίτητες, Επιθυμητές και Προαιρετικές , [IEEE98])
- Συμμετέχοντες
  - Μπορούν όλοι οι συμμετέχοντες
  - Οι διαφωνίες επιλύονται άτυπα

Μέθοδος προτεραιοποίησης με κατηγορίες (2/2)

- Θετικά
  - Εύκολη και γρήγορη μέθοδος
  - Είναι «κοινή λογική
- Κατά
  - Δεν έχουν μεγάλη ακρίβεια
  - Δεν είναι αντικειμενική μέθοδος
  - Συνήθως οι πελάτες θέτουν
    - το 85% των απαιτήσεων με μεγάλη προτεραιότητα ,
    - το 15% των απαιτήσεων με μεσαία προτεραιότητα , και
    - Το 5% των απαιτήσεων με χαμηλή προτεραιότητα .
  - Συνήθως το τελευταίο 5% ποτέ δεν υλοποιείται

Η μέθοδος του Wiegers΄ (1/3)

- Η βασική ιδέα είναι
  - Η αξία εξαρτάται από
    - Το κέρδος που δίνει στον πελάτη η υλοποίηση της απαίτησης και
    - Το πέναλτι που πληρώνουμε αν δεν υλοποιήσουμε την απαίτηση [Par96]
  - Μπορεί να χρησιμοποιηθεί μόνο για διαπραγματεύσιμες απαιτήσεις (όχι αυτές με υψηλή προτεραιότητα)

Η μέθοδος του Wiegers΄ (2/3)

- Η μέθοδος
  - Εκτιμούμε κάθε απαίτηση με κλίμακα από 1-9
    - Το κέρδος του πελάτη (benefit)
    - Το πέναλτι που πρέπει να πληρώσουμε (αν δεν το είχαμε) (penalty)
    - Το κόστος για την υλοποίηση (cost)
    - Το κίνδυνο που πιθανόν να έχουμε (risk)
  - Υπολογίζουμε το ποσοστό benefit/penalty/ cost/risk για κάθε απαίτηση

$$\text{priority} = \frac{value\%}{(cost\% \times cost, weight) + (risk\% \times risk, weight)}.$$

Η μέθοδος του Wiegers΄ (3/3)

- Θετικά
  - Σχετική μέθοδος
  - Λαμβάνει υπόψη 4 παραμέτρους
  - Το αποτέλεσμα είναι μια διατεταγμένη λίστα
  - Μπορεί να χρησιμοποιηθεί και από ομάδες
- Κατά
  - Το αποτέλεσμα εξαρτάται από την ικανότητα του ατόμου να αξιολογήσει τις παραμέτρους
  - Δεν υπάρχουν πολλά δεδομένα σχετικά με την εφαρμογή της.

Analytical Hierarchical Process

The Analytic Hierarchy Process (AHP)

- Founded by Saaty in 1980.
- It is a popular and widely used method for multi-criteria decision making.
- Allows the use of qualitative, as well as quantitative criteria in evaluation.
- Wide range of applications exists:
  - Selecting a car for purchasing
  - Deciding upon a place to visit for vacation
  - Deciding upon an MBA program after graduation.

AHP-General Idea

- Develop an hierarchy of decision criteria and define the alternative courses of actions.

- AHP algorithm is basically composed of two steps:

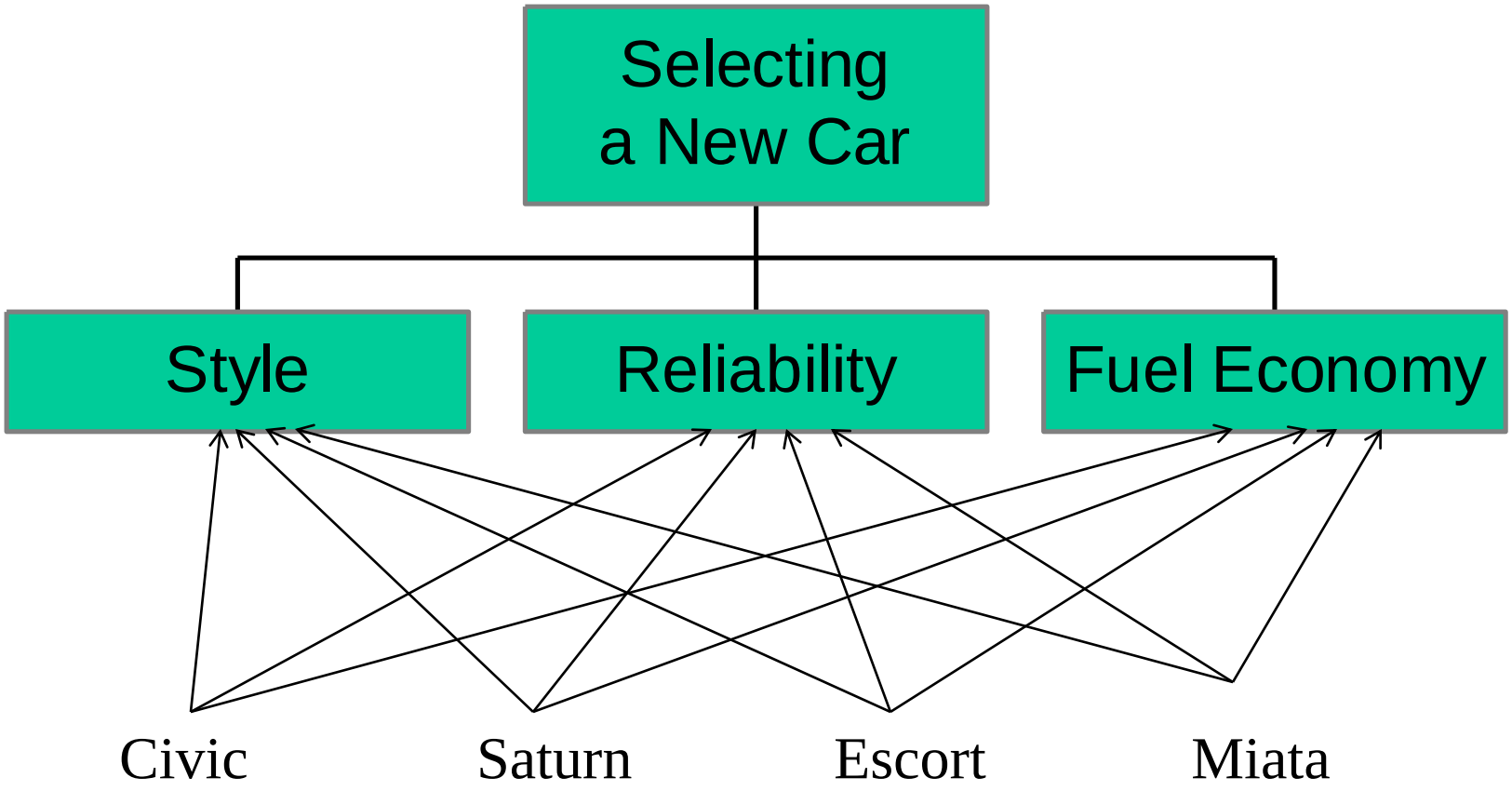
  1. Determine the relative weights of the decision criteria
  2. Determine the relative rankings (priorities) of alternatives

! Both qualitative and quantitative information can be compared by using informed judgments to derive weights and priorities.

Example: Car Selection

- Objective
  - Selecting a car
- Criteria
  - Style, Reliability, Fuel-economy **Cost?**
- Alternatives
  - Civic Coupe, Saturn Coupe, Ford Escort, Mazda Miata

Hierarchy tree



Alternative courses of action

Ranking of Criteria and Alternatives

- Pairwise comparisons are made with the grades ranging from 1-9.

- A basic, but very reasonable assumption for comparing alternatives:
- If attribute A is absolutely more important than attribute B and is rated at 9, then B must be absolutely less important than A and is graded as 1/9.

- These pairwise comparisons are carried out for all factors to be considered, usually not more than 7, and the matrix is completed.

Ranking Scale for Criteria and Alternatives

Intensity of importance	Definition	Explanation
1	Equal importance	Two factors contribute equally to the objective
3	Somewhat more important	Experience and judgement slightly favour one over the other.
5	Much more important	Experience and judgement strongly favour one over the other.
7	Very much more important	Experience and judgement very strongly favour one over the other. Its importance is demonstrated in practice.
9	Absolutely more important.	The evidence favouring one over the other is of the highest possible validity.
2,4,6,8	Intermediate values	When compromise is needed

Ranking of criteria

	Style	Reliability	Fuel Economy
Style	1	1/2	3
Reliability	2	1	4
Fuel Economy	1/3	1/4	1

Ranking of priorities

- Consider [$Ax = \lambda_{max}x$] where
  - A is the comparison matrix of size n×n, for n criteria, also called the priority matrix.
  - x is the Eigenvector of size n×1, also called the priority vector.
  - λ_{max} is the Eigenvalue, $\lambda_{max} \in \Re > n$.

- To find the ranking of priorities, namely the Eigen Vector X:

  1) Normalize the column entries by dividing each entry by the sum of the column.

  2) Take the overall row averages.

$$A = \begin{bmatrix} 1 & 0.5 & 3 \\ 2 & 1 & 4 \\ 0.33 & 0.25 & 1.0 \end{bmatrix}$$

Column sums 3.33 1.75 8.00

Normalized Column Sums →

$$\begin{bmatrix} 0.30 & 0.29 & 0.38 \\ 0.60 & 0.57 & 0.50 \\ 0.10 & 0.14 & 0.13 \end{bmatrix}$$

1.00 1.00 1.00

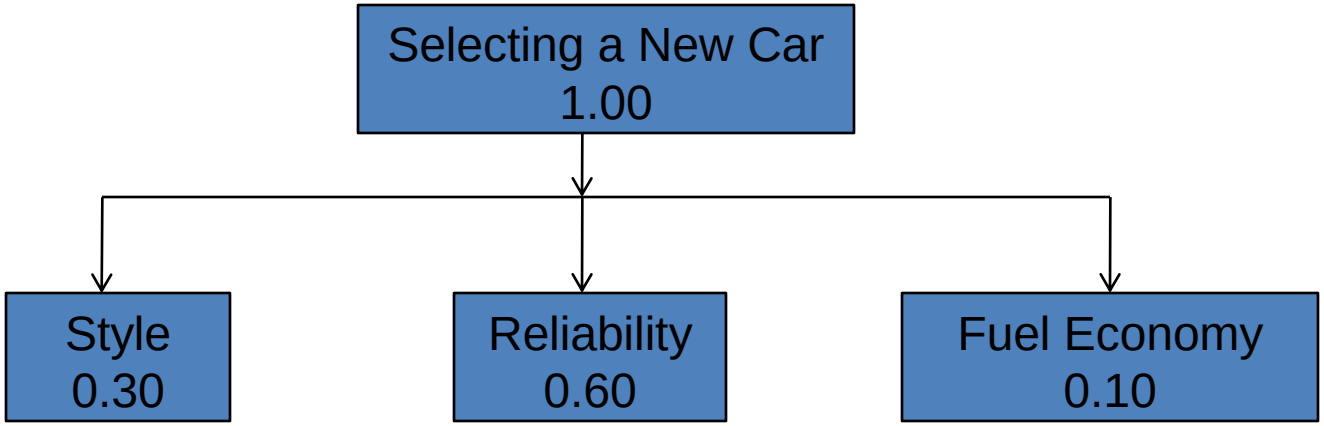
Row averages →

$$X = \begin{bmatrix} 0.30 \\ 0.60 \\ 0.10 \end{bmatrix}$$

Priority vector

Criteria weights

- Style .30
- Reliability .60
- Fuel Economy .10



Checking for Consistency

- The next stage is to calculate a Consistency Ratio (CR) to measure how consistent the judgments have been relative to large samples of purely random judgments.
- AHP evaluations are based on the aasumption that the decision maker is rational, i.e., if A is preferred to B and B is preferred to C, then A is preferred to C.
- If the CR is greater than 0.1 the judgments are untrustworthy because they are too close for comfort to randomness and the exercise is valueless or must be repeated.

Calculation of Consistency Ratio

- The next stage is to calculate λ_{max} so as to lead to the Consistency Index and the Consistency Ratio.
- Consider [Ax = λ_{max} x] where x is the Eigenvector.

$$\underset{A}{\begin{bmatrix} 1 & 0.5 & 3 \\ 2 & 1 & 4 \\ 0.333 & 0.25 & 1.0 \end{bmatrix}} \underset{x}{\begin{bmatrix} 0.30 \\ 0.60 \\ 0.10 \end{bmatrix}} = \underset{Ax}{\begin{bmatrix} 0.90 \\ 1.60 \\ 0.35 \end{bmatrix}} = \lambda_{max} \underset{x}{\begin{bmatrix} 0.30 \\ 0.60 \\ 0.10 \end{bmatrix}}$$

λmax=average{0.90/0.30, 1.60/0.6, 0.35/0.10}=3.06

- Consistency index , CI is found by

CI=(λmax-n)/(n-1)=(3.06-3)/(3-1)= 0.03

Consistency Ratio

- The final step is to calculate the Consistency Ratio, CR by using the table below, derived from Saaty's book. The upper row is the order of the random matrix, and the lower row is the corresponding index of consistency for random judgments.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.48	1.56	1.57	1.59

Each of the numbers in this table is the average of CI's derived from a sample of randomly selected reciprocal matrices of AHP method.

An inconsistency of 10% or less implies that the adjustment is small as compared to the actual values of the eigenvector entries.
A CR as high as, say, 90% would mean that the pairwise judgments are just about random and are completely untrustworthy! In this case, comparisons should be repeated.

In the above example: CR=CI/0.58=0.03/0.58=0.05

0.05<0.1, so the evaluations are consistent!

Ranking alternatives

Style	Civic	Saturn	Escort	Miata
Civic	1	1/4	4	1/6
Saturn	4	1	4	1/4
Escort	1/4	1/4	1	1/5
Miata	6	4	5	1

Priority vector

$$\begin{bmatrix} 0.13 \\ 0.24 \\ 0.07 \\ 0.56 \end{bmatrix}$$

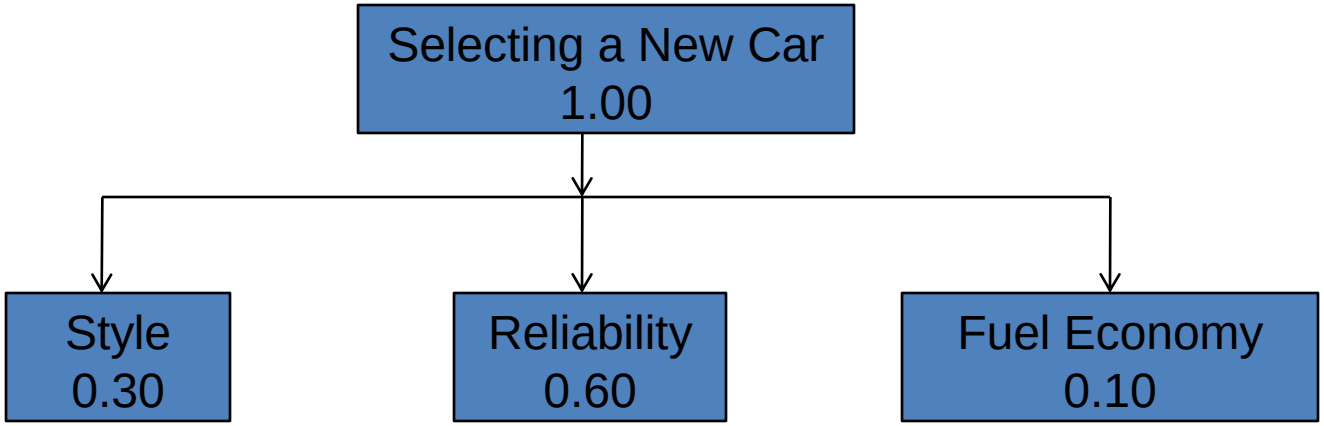
Reliability	Civic	Saturn	Escort	Miata
Civic	1	2	5	1
Saturn	1/2	1	3	2
Escort	1/5	1/3	1	1/4
Miata	1	1/2	4	1

$$\begin{bmatrix} 0.38 \\ 0.29 \\ 0.07 \\ 0.26 \end{bmatrix}$$

Ranking alternatives

		Miles/gallon	Normalized
Fuel Economy	Civic	34	.30
	Saturn	27	.24
	Escort	24	.21
	Miata	28	.25
		113	1.0

! Since fuel economy is a quantitative measure, fuel consumption ratios can be used to determine the relative ranking of alternatives; however this is not obligatory. Pairwise comparisons may still be used in some cases.



Style		Reliability		Fuel Economy	
Civic	0.13	Civic	0.38	Civic	0.30
Saturn	0.24	Saturn	0.29	Saturn	0.24
Escort	0.07	Escort	0.07	Escort	0.21
Miata	0.56	Miata	0.26	Miata	0.25

Ranking of alternatives

	Style	Reliability	Fuel Economy				
Civic	.13	.38	.30		.30		.30
Saturn	.24	.29	.24	x	.60	=	.27
Escort	.07	.07	.21				.08
Miata	.56	.26	.25		.10		.35

Priority matrix

Criteria Weights

Including Cost as a Decision Criteria

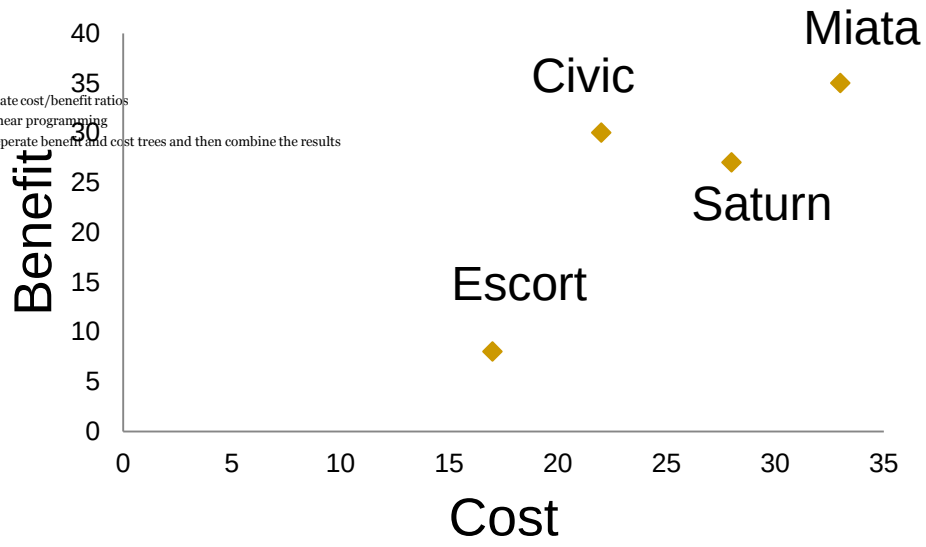
Adding “cost” as a a new criterion is very difficult in AHP. A new column and a new row will be added in the evaluation matrix. However, whole evaluation should be repeated since addition of a new criterion might affect the relative importance of other criteria as well!

Instead one may think of normalizing the costs directly and calculate the cost/benefit ratio for comparing alternatives!

	Cost	Normalized Cost	Benefits	Cost/Benefits Ratio
• CIVIC	$12K	.22	.30	0.73
• SATURN	$15K	.28	.27	1.03
• ESCORT	$9K	.17	.08	2.13
• MIATA	$18K	.33	.35	0.92

Methods for including cost criterion

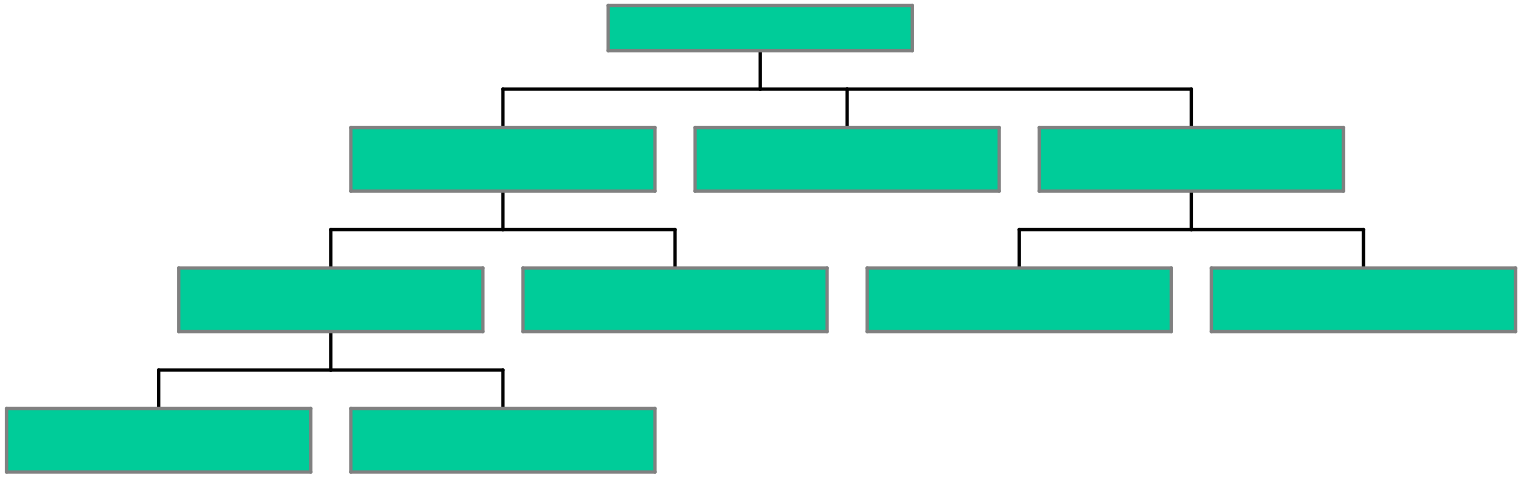
- Use graphical representations to make trade-offs.



- Calculate cost/benefit ratios
- Use linear programming
- Use seperate benefit and cost trees and then combine the results

Complex decisions

•Many levels of criteria and sub-criteria exists for complex problems.



AHP Software:

Professional commercial software Expert Choice developed by Expert Choice Inc. is available which simplifies the implementation of the AHP's steps and automates many of its computations

- computations
- sensitivity analysis
- graphs, tables

Ex 2: Evaluation of Job Offers

Ex: Peter is offered 4 jobs from Acme Manufacturing (A), Bankers Bank (B), Creative Consulting (C), and Dynamic Decision Making (D). He bases his evaluation on the criteria such as location, salary, job content, and long-term prospects.

Step 1: Decide upon the relative importance of the selection criteria:

	Location	Salary	Content	Long-term
Location	**1**	**1/5**	**1/3**	**1/2**
Salary	**5**	**1**	**2**	**4**
Content	**3**	**1/2**	**1**	**3**
Long-term	**2**	**1/2**	**1/3**	**1**

Priority Vectors:

1) Normalize the column entries by dividing each entry by the sum of the column.
2) Take the overall row averages

	Location	Salary	Content	Long-term	Average
Location	0.091	0.102	0.091	0.059	0.086
Salary	0.455	0.513	0.545	0.471	0.496
Content	0.273	0.256	0.273	0.353	0.289
Long-term	0.182	0.128	0.091	0.118	0.130
	+				+
	1	1	1	1	1

Example 2: Evaluation of Job Offers

Step 2: Evaluate alternatives w.r.t. each criteria

Location Scores

	A	B	C	D
A	1	1/2	1/3	5
B	2	1	1/2	7
C	3	2	1	9
D	1/5	1/7	1/9	1

Relative Location Scores

	A	B	C	D	Avg.
A	0.161	0.137	0.171	0.227	0.174
B	0.322	0.275	0.257	0.312	0.293
C	0.484	0.549	0.514	0.409	0.489
D	0.032	0.040	0.057	0.045	0.044

Example 2: Calculation of Relative Scores

	Relative Scores for Each Criteria					Relative weights for each criteria		Relative scores for each alternative
	Location	Salary	Content	Long-Term				
A	0.174	0.050	0.210	0.510	x	0.086	=	0.164
B	0.293	0.444	0.038	0.012		0.496		0.256
C	0.489	0.312	0.354	0.290		0.289		0.335
D	0.044	0.194	0.398	0.188		0.130		0.238

More about AHP: Pros and Cons

Pros

- It allows multi criteria decision making.
- It is applicable when it is difficult to formulate criteria evaluations, i.e., it allows qualitative evaluation as well as quantitative evaluation.
- It is applicable for group decision making environments

Cons

- There are hidden assumptions like consistency. Repeating evaluations is cumbersome. → Users should be trained to use AHP methodology.
- Difficult to use when the number of criteria or alternatives is high, i.e., more than 7. → Use GDSS / Use constraints to eliminate some alternatives
- Difficult to add a new criterion or alternative → Use cost/benefit ratio if applicable
- Difficult to take out an existing criterion or alternative, since the best alternative might differ if the worst one is excluded.

Group Decision Making

The AHP allows group decision making, where group members can use their experience, values and knowledge to break down a problem into a hierarchy and solve. Doing so provides:

- Understand the conflicting ideas in the organization and try to reach a consensus.
- Minimize dominance by a strong member of the group.
- Members of the group may vote for the criteria to form the AHP tree. (Overall priorities are determined by the weighted averages of the priorities obtained from members of the group or with geometrical average)

However;
The GDSS does not replace all the requirements for group decision making. Open meetings with the involvement of all members are still an asset.

Example 3: AHP in project management

Prequalification of contractors aims at the elimination of incompetent contractors from the bidding process.

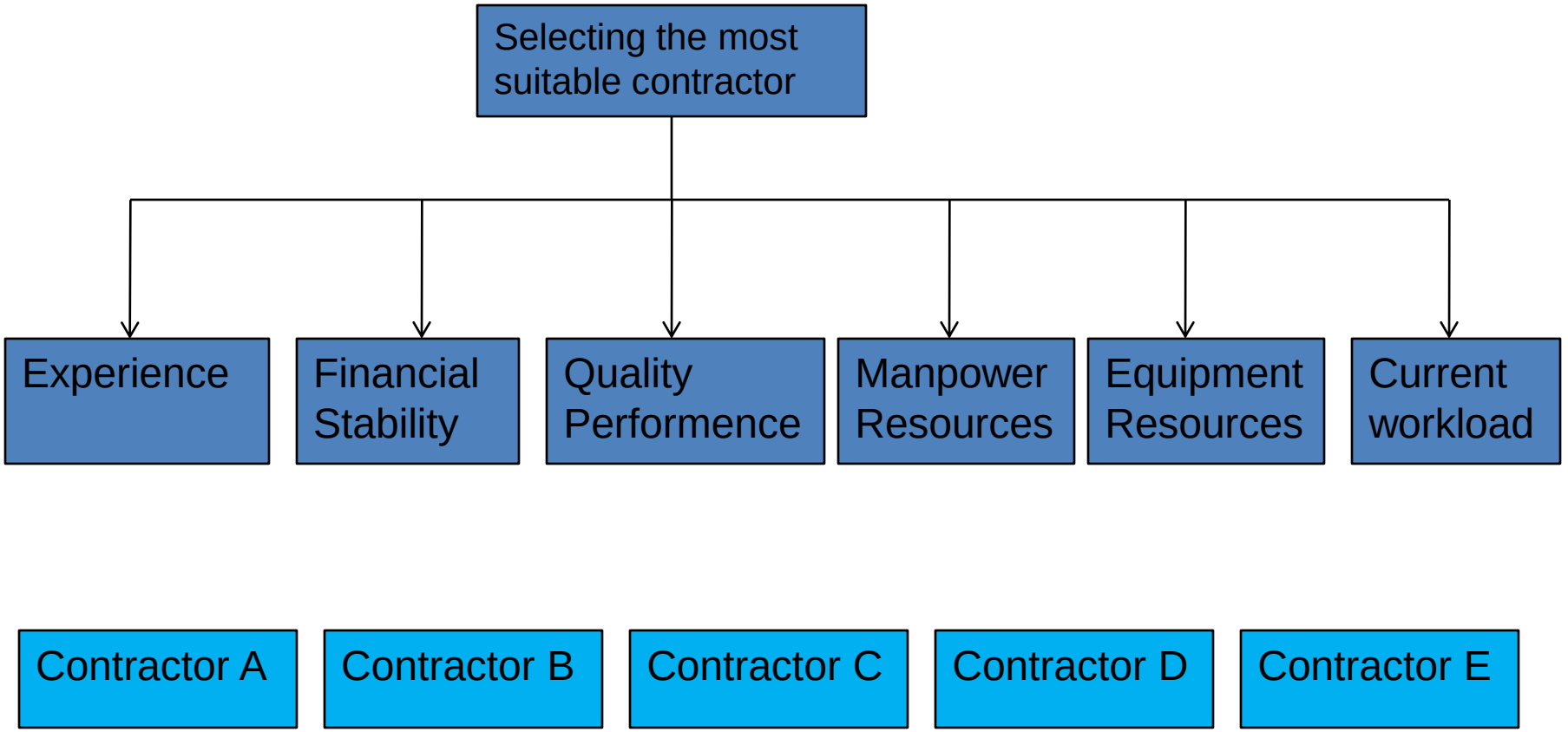
It is the choice of the decision maker to eliminate contractor E from the AHP evalution since it is not “feasible” at all !!

	Contractor A	Contractor B	Contractor C	Contractor D	Contractor E
Experience	5 years experience	7 years experience	8 years experience	10 years experience	15 years experience
	Two similar projects	One similar project	No similar project	Two similar projects	No similar project
		Special procurement experience	1 international project		
Financial stability	$7 M assets	$10 M assets	$14 M assets	$11 M assets	$6 M assets
	High growth rate	$5.5 M liabilities	$6 M liabilities	$4 M liabilities	$1.5 M liabilities
	No liability	Part of a group of companies		Good relation with banks	
Quality performance	Good organization	Average organization	Good organization	Good organization	Bad organization
	C.M. personnel	C.M. personnel	C.M. team	Good reputation	Unethical techniques
	Good reputation	Two delayed projects	Government award	Many certi®cates	One project terminated
	Many certi®cates	Safety program	Good reputation	Cost raised in some projects	Average quality
	Safety program		QA/QC program		
Manpower resources	150 labourers	100 labourers	120 labourers	90 labourers	40 labourers
	10 special skilled labourers	200 by subcontract	Good skilled labors	130 by subcontract	260 by subcontract
		Availability in peaks	25 special skilled labourers		

Example 3 (cont.'d)

	Contractor A	Contractor B	Contractor C	Contractor D	Contractor E
Equipment resources	4 mixer machines	6 mixer machines	1 batching plant	4 mixer machines	2 mixer machines
	1 excavator	1 excavator	2 concrete transferring trucks	1 excavator	10 others
	15 others	1 bulldozer	2 mixer machines	9 others	2000 sf steel formwork
		20 others	1 excavator		6000 sf wooden formwork
		15,000 sf steel formwork	1 bulldozer		
			16 others		
			17,000 sf steel formwork		
Current works load	1 big project ending	2 projects ending (1 big+ 1 medium)	1 medium project started	2 big projects ending	2 small projects started
	2 projects in mid (1 medium +1 small)		2 projects ending (1 big + 1 medium)	1 medium project in mid	3 projects ending (2 small + 1 medium)

Hierarchy Tree



Example 3: AHP in project management

Step 1: Evaluation of the weights of the criteria

Pair-wise comparison matrix for the six criteria[a]

	Exp.	FS	QP	MPR	ER	CWL	Priority vector
Exp.	1	2	3	6	6	5	0.372
FS	1/2	1	3	6	6	5	0.293
QP	1/3	1/3	1	4	4	3	0.156
MPR	1/6	1/6	1/4	1	2	1/2	0.053
ER	1/6	1/6	1/4	1/2	1	1/4	0.039
CWL	1/5	1/5	1/3	2	4	1	0.087
							$\sum = 1.00$

[a] $\lambda_{max} = 6.31$, CI = 0.062, RI = 1.24, CR = 0.05 < 0.1 OK.

Step 2: a) Pairwise comparison matrix for experience

Exp.	A	B	C	D	E
A	1	1/3	1/2	1/6	2
B	3	1	2	1/2	4
C	2	1/2	1	1/3	3
D	6	2	3	1	7
E	1/2	1/4	1/3	1/7	1

Exp.	A	B	C	D	E	Priority vector
A	0.08	0.082	0.073	0.078	0.118	0.086
B	0.24	0.245	0.293	0.233	0.235	0.249
C	0.16	0.122	0.146	0.155	0.176	0.152
D	0.48	0.489	0.439	0.466	0.412	0.457
E	0.04	0.061	0.049	0.066	0.059	0.055
						$\sum = 0.999$

[a] $\lambda_{max} = 5.037$, CI = 0.00925, RI = 1.12, CR = 0.0082 < 0.1 OK.

Example 3: AHP in project management

Calculation of priority vector:

	Exp. (0.372)	FS (02.93)	QP (0.156)	MPR (0.053)	ER (0.039)	CWL (0.087)
A	0.086	0.425	0.269	0.151	0.084	0.144
B	0.249	0.088	0.074	0.273	0.264	0.537
C	0.152	0.178	0.461	0.449	0.556	0.173
D	0.457	0.268	0.163	0.081	0.057	0.084
E	0.055	0.039	0.031	0.045	0.038	0.062

$$\times \begin{bmatrix} 0.372 \\ 0.293 \\ 0.156 \\ 0.053 \\ 0.039 \\ 0.087 \end{bmatrix} = \begin{bmatrix} 0.222 \\ 0.201 \\ 0.241 \\ 0.288 \\ 0.046 \end{bmatrix}$$

Probably Contractor-E should have been eliminated. It appears to be the worst.

Note that a DSS supports the decision maker, it can not replace him/her. Thus, an AHP Based DSS should allow the decision maker to make sensitivity analysis of his judgements on the overall priorities !

- Method
  - n requirements are setted up in the rows and columns of the n x n –matrix
  - Pair-wise comparison of all the requirements according the criterion from 1 to 9

Pair-wise comparison (AHP) (1/6)

Pair-wise comparison (2/6)

1	Of equal value
3	Slightly more value
5	Essential or strong value
7	Extreme value
9	Intermediate value

Cumulative Voting, the 100-Dollar Test

- The 100-dollar test is a very straightforward prioritization technique where the stakeholders are given 100 imaginary units (money, hours, etc.) to distribute between the requirements
- The result of the prioritization is presented on a ratio scale

Cumulative Voting, the 100-Dollar Test

- One should only perform the prioritization once on the same set of requirements, since the stakeholders might bias their evaluation the second time around if they do not get one of their favorite requirements as a top priority

Top-Ten Requirements

- In this approach, the stakeholders pick their top-ten requirements (from a larger set) without assigning an internal order between the requirements
- This makes the approach especially suitable for multiple stakeholders of equal importance

Top-Ten Requirements

- The reason to not prioritize further is that it might create unnecessary conflict when some stakeholders get support for their top priority and others only for their third priority
- It is not advisable to take average across all stakeholders since it might lead to some stakeholders not getting any of their top requirements

Top-Ten Requirements

- The main challenge in this technique is to balance issues related to the fact that top priority requirements of all stakeholders are included in the next development activity

Comparison of the methods

	Prioritization scales	**Wieger`s method**	**Pair-wise comparison**
Difficulty	Easy	Medium	Difficult
Work needed	Little	Medium	A lot
Results	Rough	Clear	Clear

References

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- [Moi00] Moisiadis Frank, Prioritising Use Cases and Scenarios, IEEE 2001
- [Wie99] Wiegers, K., Software Requirements, Microsoft Press, Redmond, Washington, 1999.