AN AHP BASED DECISION MAKING MODEL FOR PROJECT MANAGEMENT IN PUBLIC SECTOR

JSPM
JOURNAL OF STRATEGY & PERFORMANCE MANAGEMENT

Nadeem I Kureshi, Center for Advanced Studies in Engineering, Islamabad, Pakistan. nadeemk@case.edu.pk.

Citation: Kureshi, N. I. (2016). An AHP based decision making model for project management in public sector, Journal of Strategy and Performance Management, 4(2), 61-72.

BACKGROUND

Decision making takes place in businesses all the time. On many instances, it entails comparing options and selecting the best ones, often in presence of many constraints. For example, an organization may have to select one out several proposed projects, with a budget ceiling. However, constrains are not always clearly discernible and even the best thought out decisions can face challenges such as, inter alia (See for example, Santos & Rosati, 2015, LeBlanc, McConnell & Monteiro, 2015; Zwaan et. al., 2016, Mays, Pope & Popay, 2005, Elsawah et. al.,2015):

- All stakeholders do not agree on a single solution, though constraints do not allow multiple solutions.
- Different stakeholders may have sponsored/ advocated different proposals, thus have a natural tendency to prefer their own projects.
- Stakeholders have subjective opinion about their choices and they may not be able to convince others about the appropriateness of their choice, particularly when other have their own subjective opinions.
- Deciding stakeholders are normally influenced by one or more cognitive biases, unless they are made cognizant of such biases and agree to address them.
- Decisions may have multiple variables, and may overpower the decision makers ability to process the information. This problem increases with increasing number of variables.
- Decision variables may be a combination of qualitative and quantitative aspects.
- Most decision making situations are time constrained, thus inhibiting granularity.

A compounding factor is that decision making in most organization is carried out in a fashion where a sponsor is asked to 'advocate' his proposal while decision makers act as judges. Such approach brings many problems such as:

- Advocate is biased towards his/ her own proposal, and thus, may not always be rational.
- Advocate chooses what to present and what not to present, thus 'driving' the decision makers.
- Decision makers, while acting as judges are not always best prepared on different aspects of all advocated proposals.
- Decision makers may have emotional biases for one of the alternates available or the person advocating an alternate.

To overcome such problems, several tools have been proposed to help decision makers. Such tools have nuanced advantages and limitations. This paper explains one such tool called Analytical Hierarchy Process (AHP) through an actually applied, step-by-step example.

ANALYTICAL HIERARCHY PROCESS

AHP was proposed by Thomas L Satty in 1980 and is used widely for multi criteria decision making. It allows use of both qualitative and quantitative criteria. The tool uses simple matrix multiplication as its mathematical engine (Ho, Xu, & Dey, 2010).

One of the fundamental premises of AHP is a belief that humans are better at making comparative assessments as compared to making absolute assessments (Srdjevic, 2015).

The AHP process has following steps.

What	How	Outcome
1. Finalize the set of criteria and sub-criteria, which will be used as the basis of competitive assessment between available options.	Through a strategic decision making meeting, involving senior management, sponsors and process owners.	Finalized list of criteria and sub-criteria.
2. a. Comparatively assess the criteria list made in step 1. 2. b. Prioritize the criteria based on comparative matrix.	2.a. Through a strategic decision making meeting, involving senior management and sponsors. 2. b. Solve the comparative matrix.	2. a. A comparative matrix of criteria that has number of rows and columns equal to the number of finalized criteria. 2. b. A priority matrix that has one column, and rows equal to the number of finalized criteria.
3. Ascertain that your prioritization was consistent.	Find Consistency Ratio (CR) and repeat prioritization activity if the ratio is above the acceptable limit.	Consistency Ratio (CR) within acceptable limit.

What	How	Outcome
4. a. For each criterion, comparatively assess the available alternates.	4. b. By experts who have evaluated all available alternatives.	4. a. One comparative matrix each for every criteria, that have number of rows and column equal to the number of available alternates.
4. b. Prioritize the available alternatives for each criterion.	4. b. Solve the comparative matrix.	4. b. A priority matrix ranking all available alternates against criteria, that has number of columns equal to the number of available alternatives and number of rows equal to the number of criteria.
5. Ascertain that your prioritization of available alternatives was consistent.	Find Consistency Ratio (CR) and repeat prioritization activity if the ratio is above the acceptable limit.	Consistency Ratio (CR) within acceptable limit.
6. Solve the outcomes of Steps 2.b and 4.b.	Solve the matrices.	Prioritized alternatives for decision making

PRACTICAL APPLICATION

The organization under study is a public sector organization located in Islamabad, Pakistan. Historically, following process was followed for selection of projects:

- Each of the 15 Strategic Business Units (SBU) of the organization proposed various projects, after they had some insight into available budget for upcoming financial year.
- Because every SBU wanted its projects to go through, 45-50 project proposals were received for each financial year.
- A Prioritization Committee prioritized the projects, categorizing each as Priority-I, Priority-II or Priority-III project. The number of P-I projects was set to correspond to about 120% of the available projects budget to cater for last minute drop outs. P-II would generally mean stand-by for P-I and expected forerunners for next prioritization cycle. P-III were low key projects.
- Each P-I project sponsor was required to advocate its case in front of a board of senior most management. The management would decide to go ahead with it or otherwise after the advocacy.

The pilot project under discussion was undertaken in year 2015. Instead of the usual cycle described above, the organization conducted a facilitated workshop which was mandated to short list a set of criteria and sub criteria after thorough discussion among all stakeholders. It was decided that the judgment criteria for projects prioritization will be 'Financials (C1)', 'Duration (C2)', 'Strategic Alignment (C3)' and 'Non-financials (C4)'. Following were the sub-criteria against each main criteria:

Criteria	Sub-Criteria
C1 Financials	C11 - Cost, measured as total $ life cycle cost. C12 - ROI, measured as a figure reflecting %age return over lifecycle and breakeven point.
C2 Duration	C21 - Scheduled Duration, measured as inverse of weeks of planned activities above 12 months. C22 - Expected Delays, measured as average of EXD score given by a panel of 4-6 experts.
C3 Strategic Alignment	No sub-criteria, measured as average of STA score given by a panel of 4-6 experts.
C4 Non Financials	C41 - HR Development, measured as average of HRD score given by a panel of 4-6 experts. C42 - Own Resource Commitment, measured as an average of ORC score given by a panel of 4-6 experts. C43 - Long-Term Impact, measured as an average of LTI score given by a panel of 4-6 experts. C44 - CSR Impact, measured as an average of CSR score given by a panel of 4-6 experts.

Table 1: Criteria and Sub-criteria

Step 1 - FINALIZE CRITERIA: Criteria shown in Table 1 was agreed by all stakeholders. Approximate duration of the activity was 4 hours. For the sake of simplicity, this paper does not include detailed discussion on how criteria values were developed through combining different, finalized sub-criteria.

Step 2 - PRIORITIZE CRITERIA: Comparative matrix of criteria was developed by the Board with selected process owners. Approximate duration of the activity was 1 hour. Following was the outcome:

	C1	C2	C3	C4
C1	**1**	2	0.5	1
C2	0.5	**1**	0.33	0.5
C3	2	3	**1**	1.5
C4	1	2	0.66	**1**

Table 2: Comparative Matrix for Criteria

Following are some of the important notes that will help understand development of this 4x4 matrix:

- All cell that have same criteria in rows as columns have a fix value of 1.
- All board members were asked to answer the question, 'How important is C1, when compared to C2?'. The average number from 15 respondents was 2 (i.e. C1 is twice as important as C2) therefore you see '2' in the cell crossing row C1 (RC1) and column C2 (CC2). Cells RC1xCC3, RC1xCC4, RC2xCC3, RC2xCC4 and RC3xCC4 were filled similarly.
- Since the cell crossing row C2 (RC2) and column C1 (CC1) is mathematical opposite of the cell crossing row C1 and column C2, you see 0.5 (inverse of 2) there. Cells RC3xCC1, RC4xCC1, RC3xCC2, Rc4xCC2 and Rc4xCC3 were filled similarly.
- Note that cells RC1xCC4 and RC4xCC1 have a value of 1. This is only because the board thought they are equally important. Cel RC1xCC4 may have taken any other value depending on the board's opinion and cell Rc4xCC1 would have been its mathematical inverse.

Next part of Step 2 is to generate a priority matrix from the 4x4 matrix (Table 2). It is done in following steps:

1. Normalize[1] the matrix. It is done by getting the column sum and dividing each entry by the column sum. Illustration is given in the illustration below.

2. Take row averages. Illustration is given in the illustration below.

$$\begin{pmatrix} 1 & 2 & 0.5 & 1 \\ 0.5 & 1 & 0.33 & 0.5 \\ 2 & 3 & 1 & 1.5 \\ 1 & 2 & 0.66 & 1 \end{pmatrix} \rightarrow \begin{pmatrix} 0.22 & 0.26 & 0.20 & 0.26 \\ 0.11 & 0.13 & 0.13 & 0.13 \\ 0.44 & 0.38 & 0.40 & 0.38 \\ 0.22 & 0.25 & 0.27 & 0.25 \end{pmatrix} \rightarrow \begin{pmatrix} 0.23 \\ 0.12 \\ 0.40 \\ 0.25 \end{pmatrix}$$

The row average matrix above having 1 column and 4 rows is called Priority Matrix. It shows that as per board's opinion, C3, i.e. Strategic Alignment is the most important prioritization factor for projects (with a value of 0.40), followed by Non-Financials (0.25), Financials (0.23) and Duration (0.12) respectively. This completes step 2.

Step 3 - ASCERTAIN CONSISTENCY OF CRITERIA PRIORITIZATION: Step 3 is for ascertaining that the prioritization values given by experts were consistent. Consistency here means, that if they have indicated that A was more important than B and B was more

[1] Normalization is used to minimize data redundancy. It is done by brining all data points to a notionally common scale. In this case, the scale is 1. Note that, after normalization, column sums of all columns is 1.

important than C, then their valuation of A should always be higher than C. This might seem a trivial step for this 4x4 matrix; after all, why would someone not be able to meet this simple consistency requirement. However, it becomes pretty difficult to achieve when the order of matrix increases. An average manager will find it really hard to allocate consistent priority values to a 7x7 or 8x8 matrix.

Consistency is ascertained through following steps:

3.1. Multiply the original (non-normalized) 4x4 matrix by the 4x1 Priority Vector.

3.2. Divide each entry of the resultant 4x1 matrix by corresponding entry of 4x1 Priority Vector.

3.3. Take average of the 4 values. This is called **λ**max.

3.4. Find Consistency Index (CI) by the formula $CI = \frac{(\lambda \max - n)}{n-1}$, where n is the order or original matrix, which in this case is 4 (4 rows/columns).

3.5. Find Consistency Ratio (CR) by dividing CI by a constant for corresponding matrix order from the following table from Satty's book. In this case, the matrix order is 4, thus the constant is 0.90. If CR is less than 0.1, this indicates that the judgement was consistent. For higher values, the entire cycle is repeated to come up with consistent results, i.e. a CR of 0.1 or less.

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

Table 3: Constants for Calculating CR

Following is a step wise illustration of finding CR:

3.1. $$\begin{pmatrix} 1 & 2 & 0.5 & 1 \\ 0.5 & 1 & 0.33 & 0.5 \\ 2 & 3 & 1 & 1.5 \\ 1 & 2 & 0.66 & 1 \end{pmatrix} \text{x} \begin{pmatrix} 0.23 \\ 0.12 \\ 0.40 \\ 0.25 \end{pmatrix} = \begin{pmatrix} 0.92 \\ 0.49 \\ 1.60 \\ 0.98 \end{pmatrix}$$

3.2. 0.92/0.23 + 0.49/0.12 + 1.60/0.40 + 0.98/0.25) = 16.02

3.3. **λ**max = 16.02/4 = 4.004

3.4. $$CI = \frac{(\lambda \max - n)}{n-1}$$

$$CI = \frac{(4.004 - 4)}{4 - 1} = 0.00166$$

3.5. CR = CI/Constant = 0.00166/0.90 = 0.0018.

Since the CR is less than 0.1, the judgements of 15 board members were consistent. If you would like to experiment with CR, try changing the value of cell RC1xCC3 to 4 (and putting its inverse, 0.25, in cell RC3xCC4). Your CR will now be 0.37, thus inconsistent judgements.

Step 4 - COMPARATIVE ASSESSMENT OF AVAILABLE ALTERNATES FOR EACH CRITERIA: 4 projects were short listed by the organization for this exercise, 2 out of them were to be finalized, and thus selected fur funding. Lets calls these 4 projects as Project-1 (P1), Project-2 (P-2), Project-3 (P-3) and Project-4 (P-4). This step is about prioritizing each available alternative on each of the 4 criteria. Thus we will have 4 prioritization matrices.

Before we begin solving for Step 4, lets understand that different criteria will have different inputs for the ranking candidate projects. Quantitive criteria, such as Financial (C-1) will get values straight from the account books in the following shape.

Calculating Priority Matrix for C-1

Note that the normalized values here indicate that under the 'Financials' criteria, i.e. C-1, P-3 ranks highest, followed by P-1, P-2 and P-4 respectively.

	Financials	**Normalized Values**
P-1	195m	0.28
P-2	157m	0.22
P-3	215m	0.30
P-4	134m	0.19

Table 4: Comparative Matrix for C-1

The values in the column 'Normalized Values' will become the resultant vector for C-1, as follows:

Priority Matrix for C1: $\begin{pmatrix} 0.28 \\ 0.22 \\ 0.30 \\ 0.19 \end{pmatrix}$

Since C1 was a fairly straightforward quantitative criteria, with values coming from accounts books, no opinion seeking was required, thus no calculations. However, all other criteria are either partially or completely quantitative.

Calculating Priority Matrix for C-3

Following is the process used for ranking the 4 candidate projects on the criteria C3, i.e. Strategic Alignment. As with the original criteria matrix, the values came from calculating average of the comparative assessment given by experts with thorough knowledge of each candidate project.

Ask the experts the following question: 'In terms of Strategic Alignment (SA), how better (or worse) is P-1, when compared to P-2?' The average will give you figure for cell RP1xCP2 (0.33). All other values above the 1 diagonal are put in similarly. Remember cells where same values cross each other are marked as 1 and every value you put in gets a mathematical inverse in its corresponding cell. As we did with the comparative matrix of criteria, (Part 2 of Step 2 above) the matrix will be normalized and row averages will be calculated, to come up with resultant priority matrix, which is as follows:

STA	**P-1**	**P-2**	**P-3**	**P-4**
P-1	**1**	0.33	0.5	0.66
P-2	3	**1**	1.5	0.66
P-3	2	0.66	**1**	1.5
P-4	1.5	1.5	0.66	**1**

Table 5: Comparative Matrix for C-3

Priority Matrix for C3: $\begin{pmatrix} 0.13 \\ 0.32 \\ 0.28 \\ 0.27 \end{pmatrix}$

Calculating Priority Matrix for C-2 and C-4

We will now calculate priority matrix for the remaining 2 criteria. Remember that there is no particular order for calculating the priority matrices for different criteria. Following are the tables comparing available alternates for C2 (Duration) and C4 (Non-Financials):

DUR	P-1	P-2	P-3	P-4
P-1	**1**	1.5	2	2
P-2	0.66	**1**	2	0.5
P-3	0.5	0.5	**1**	1
P-4	0.5	2	1	**1**

Table 6: Comparative Matrix for C-2

NF	P-1	P-2	P-3	P-4
P-1	**1**	3	2	1.5
P-2	0.33	**1**	0.25	0.66
P-3	0.5	4	**1**	1.5
P-4	0.66	1.5	0.66	**1**

Table 7: Comparative Matrix for C-4

Priority matrices for C2 and C4, calculated from the 2 comparative matrices above, are given below:

Priority Matrix for C2: $\begin{pmatrix} 0.36 \\ 0.22 \\ 0.17 \\ 0.24 \end{pmatrix}$

Priority Matrix for C4: $\begin{pmatrix} 0.39 \\ 0.11 \\ 0.30 \\ 0.20 \end{pmatrix}$

Step 5 - ASCERTAIN CONSISTENCY OF ALTERNATIVES PRIORITIZATION:In Step 5, we will prove that the comparative rankings assigned to available alternates (4 projects) for all criteria were consistent (Procedure explained in Step 3). Following are the calculated values for proving consistency of comparative ranking for C2 and C4. Since all CR values are below 0.10, the assigned comparative rankings were consistent.

	λmax	CI	CR
C2	4.16	0.054	0.060
C3	4.20	0.064	0.071
C4	4.10	0.035	0.039

Table 8: Consistency Values for C-1, C-2 and C-3

Step 6 - CALCULATE FINAL RANKING OF ALTERNATIVES: In this final step, we will combine the 4 priority matrices we have calculated for each criteria (in Step 4) in a single 4x4 matrix and multiply it with the criteria priority matrix calculated in Step 2.

	C1 (FIN)	C2 (DUR)	C3 (STA)	C4 (NF)
P1	0.28	0.36	0.13	0.39
P2	0.22	0.22	0.32	0.11
P3	0.3	0.17	0.28	0.3
P4	0.19	0.24	0.27	0.2

Table 9: Combined Comparative Matrix for C-1, C-3, C-3 and C-4

Combined Priority Matrix x **Priority Matrix** = **Final Ranking of Alternatives**

$$\begin{pmatrix} 0.28 & 0.36 & 0.13 & 0.39 \\ 0.22 & 0.22 & 0.32 & 0.11 \\ 0.30 & 0.17 & 0.28 & 0.30 \\ 0.19 & 0.24 & 0.27 & 0.20 \end{pmatrix} \times \begin{pmatrix} 0.23 \\ 0.12 \\ 0.40 \\ 0.25 \end{pmatrix} = \begin{pmatrix} 0.257 \\ 0.232 \\ 0.276 \\ 0.230 \end{pmatrix}$$

RESULTS

The resultant matrix is our Final Ranking of Alternatives, indicating that P3 has scored highest overall (0.276) followed by P1 (0.257). As the organization could fund only two of the four candidate projects in 2015, it decided to fund P3 and P1.

The combined priority matrix in Table 9 contains three types of criteria:

1. Quantitative (Financial), which, when expressed as normalized financial figures, formed the priority matrix for Criteria C1; thus did not require matrix calculations (Steps 4a and 4b) or proof of consistency (Step 5).
2. Qualitative (Strategic Alignment and Non-Financials), which was based on comparative assessment by experts and thus went through Steps 4a, 4b and 5.
3. Mixed, i.e. both quantitative and qualitative (Duration), one sub-criteria being quantitative (scheduled duration) and qualitative (expected delays).

AHP has thus facilitated decision making by solving the three types of criteria, which, when attempted by intuition alone, can be highly susceptible to decision making biases.

Readers must also note that some of the sub-criteria, which were handled as qualitative (for example, C41 and C43) in this case study, could well be quantitative in different settings. For instance, an organization may decide to measure C41 directly as training funds allocated in the project proposals.

This discussion of whether intuition of experts should be pressured over hard figures, is a highly contested topic in scholarly literature. It is however, not in the scope of instant work. Future works may like to investigate such cases by solving such decision making situations in both ways and comparing the results. An even deeper research can compare the short term and long term outcomes of such decisions and ascertain which decision making method (qualitative or quantitative) turned out to be more accurate.

This paper does not elaborate the process how qualitative and quantitative methods were combined through aggregation of scores from expert opinion and hard numbers. A future work can elaborate this aspect and propose new ways of doing it more efficiently. Similarly, some limitations have been outlined in the Discussion section below, which can also be addressed in future works.

DISCUSSION

This paper has attempted to remain as simple as possible. It has briefly described the process used to rank available alternatives using Analytical Hierarchy Process, illustrated through an actual example of prioritizing candidate projects. While this illustration will surely help a practitioner interesting in implementing AHP in his/ her work; an academic scholar will certainly see various limitations of this paper including:

- There are more than one ways to solve a matrix in order to get the priority matrix. The method we used (normalization followed by row averages) is perhaps the least complex. Other available methods are complex but will increase accuracy of results. The values in this case were also solved through two other popular methods, with maximum resultant accuracy of about 0.4% higher than what we got with this method.

- The process of facilitated workshops has not been defined in detail. Thus many questions can arise related to adequateness of the process.

- Workshops were conducted to 'neutralize' the respondents, thus reducing the probability of biases. The workshops also included exercises to normalize the respondents, thus ensuring that they do not assign too low or too high values, comparatively. Details have not been discussed in the paper.

REFERENCES

Mays, N., Pope, C., & Popay, J. (2005). Systematically reviewing qualitative and quantitative evidence to inform management and policy-making in the health field. Journal of health services research & policy, 10 (suppl 1), 6-20.

Ho, W., Xu, X., & Dey, P. K. (2010). Multi-criteria decision making approaches for supplier evaluation and selection: A literature review. European Journal of Operational Research, 202(1), 16-24.

Elsawah, S., Guillaume, J. H., Filatova, T., Rook, J., & Jakeman, A. J. (2015). A methodology for eliciting, representing, and analysing stakeholder knowledge for decision making on complex socio-ecological systems: From cognitive maps to agent-based models. Journal of environmental management, 151, 500-516.

Hahn, W. J. (2015). Making decisions with multiple criteria: a case in energy sustainability planning. EURO Journal on Decision Processes, 3(1-2), 161-185.

Srdjevic, B., Pipan, M., Srdjevic, Z., Blagojevic, B., & Zoranovic, T. (2015). Virtually combining the analytical hierarchy process and voting methods in order to make group decisions. Universal Access in the Information Society, 14(2), 231-245.

Zwaan, L., Monteiro, S., Sherbino, J., Ilgen, J., Howey, B., & Norman, G. (2016). Is bias in the eye of the beholder? A vignette study to assess recognition of cognitive biases in clinical case workups. BMJ quality & safety, bmjqs-2015.

LeBlanc, V. R., McConnell, M. M., & Monteiro, S. D. (2015). Predictable chaos: a review of the effects of emotions on attention, memory and decision making. Advances in Health Sciences Education, 20(1), 265-282.

Santos, L. R., & Rosati, A. G. (2015). The evolutionary roots of human decision making. Annual review of psychology, 66, 321.