AN ANALYSIS OF THE PROCESS IN DERIVING FURTHER BENEFITS OF AN AHP MODEL

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ABSTRACT

This paper deals with evaluation of benefits from the AHP methodology that can improve the quality of the decision making process. In this research effort, evaluation (give second opinions) of another's assessment of goal is carried out, wherein, the criteria assessment is different while keeping the alternatives assessment with respect to each criteria constant, to test if the priority vector of the alternatives is same or different.

Keywords: AHP process, subjectivity, pair-wise assessments.

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1. Introduction

Making decisions involve evaluating the available alternatives and choosing the right one that meets a desired objective. Underlying assumption is our ability to compare, and measure or assess the value of these alternatives with the respect to the goal at hand. It is one of main functions and responsibilities of senior management in organizations. Decision-making is a fundamental process that is integral in everything we do (Saaty, 2004). It is not surprising to know that one of the main goals of education is to help students/participants in the study to make better decisions and increase objectivity in making such decisions. However, subjectivity cannot be completely eliminated because we interpret and make inferences based on objective assessments of the data.

Analytical Hierarchy Process, a decision-making methodology developed by Saaty (1987) is an attempt in this direction. AHP can be used in any situation where the presence of multiple influencing factors and decision criteria make it difficult to understand the interactions among them intuitively. In such cases AHP offers a structured approach to reduce the complexity and help us in making a decision objectively.

Saaty (2004) argues that subjective judgments using qualitative parameters are not necessarily inferior to physical quantitative measures. He contends that physical scale measurements only help in interpretation and in our understanding and use of the things that we already know how to measure.

Although, AHP is practiced in industry and academics, it presents a few concerns and opportunities for further research. One of the concerns is that subjectivity. Although subjectivity cannot be eliminated completely, with better analysis, objectivity can be improved. In this paper, using the AHP methodology, we propose to evaluate or provide second opinion of another person's assessment of a goal to improve objectivity. With this approach, the second opinion of the criteria assessment is different while keeping the alternatives assessment with respect to each criteria the same and test if the priority vector of the alternatives is same or different.

The remainder of the paper presents a brief literature review about the analytical hierarchy process followed by hypothesis of the study and research design. Following these, we present data presentation and analysis. We conclude the paper with limitations and future scope.

2. Literature Review

The primary objective of AHP is to classify a number of alternatives by considering a given set of qualitative and quantitative criteria and using pair-wise comparisons/judgments. AHP results in a hierarchical leveling of the quality determinants, where the upper hierarchy level is the goal of the decision process, the next level defines the selection criteria which can be further subdivided into sub criteria at lower hierarchy levels and, finally, the bottom level presents the alternative decisions.

Analytic Hierarchy Process (AHP) is one of the multi-criteria decision making methods that was originally developed by Saaty (1987). It is a method to derive ratio scales from paired comparisons to determine relative weights and use them for evaluating alternatives. The input can be obtained from actual measurement such as price and weight or from subjective opinion such as satisfaction feelings and preference. AHP has a provision for a small inconsistency (10%) in judgment because it is difficult to be absolutely consistent. The ratio scales are derived from the principal eigenvectors and the consistency index is derived from the principal eigenvector value (Saaty, 2008).

It is well known that AHP is associated with large computing and subjectivity (Rang-guo & Yan-ni, 2004). In an effort to improve quality of decisions, Stern, Meherez, and Hadad (2000) suggested a hybrid approach of using data envelopment analysis (DEA) and AHP to take best of both and avoid pitfalls of each method. The Peters-Zelewski (2008) paper looks at a discussion of the pit-falls of AHP from understanding differences between relative versus absolute measurements, clustering of direct measurements, and integrated view of inputs and outputs.

Considering the above research findings, our research objective is to understand the inherent subjectivity of pair-wise comparisons via the tool of reciprocal assessments. And to overcome the subjectivity issue, we propose to use research methodology involving evaluation of second opinion of another person's assessment of a goal to improve objectivity.

3. Hypotheses/Objectives

Our research goal is to improve the quality of decision using AHP by inserting second opinion of a person's assessment to examine variations in choosing the alternative.

4. Research Design/Methodology

In this research study, we found that without a strong understanding of the AHP technique, the respondents in the pilot survey found it difficult to provide consistent judgment. Hence, we have sought four pair-wise comparisons for the criteria table and two for each of the project judgments (for every criteria) to derive a consistent set of all pair-wise comparisons.

- Using literature review, Rich (2012), Sulemani (2009), Hibner (2011) and interviews with Scrum Masters, we have derived a prioritized list of factors influencing the success for Scrum projects. Five factors were identified, for assessing their influence and impact on success, Scrum process understanding/compliance (Factor 1), Clarity of Scrum Projects i.e. roles and responsibilities(Factor 2), Effectiveness of Scrum Master(Factor 3),Customer – Degree of Product Owner involvement (Factor 4), Team collaborative environment (Factor 5).
- The survey questionnaire included two components: general profile (role in project, years of experience, educational qualification, number of scrum projects, number of scrum masters, type of project, size of organization, and part 2 included AHP parameters for gauging the influence of various factors (mentioned above) on success or failure in Scrum project.
- For the pair-wise comparisons we used a verbal scale of moderate, strong, very strong and extreme and neutral and converted them into a numerical scale of 2,4,6,8 respectively. The pair-wise comparisons for two respondents are shown in Appendix 1.

5. Data/Model Analysis

For data collection, survey was used to obtain responses from 17 people of which 65% of respondents were scrum masters (project managers), 23% of them software developers and the remaining are technical leads. Everyone was asked to assess 3 projects from their respective organizations. The summary of the survey results is as follows:

- All the responding organizations use scrum methodology. Of these, 31% of the respondents' organizations are small, 19% are medium, and the remaining 50% of the organizations are large.
- The small- and medium-size organizations execute 3-9 scrum projects routinely while large organizations deal with at least 25 projects, which are in progress.

Factor	Scrum Process Understanding /compliance	Clarity of Scrum Project i.e. roles & responsibilities (Factor 2)	Effectiveness of Scrum Master (Factor 3)	Degree-Product Owner involvement (Factor 4)	Team collaborative environment (Factor 5)	Eigenvector
Factor 1	1	1/6	6	8	2	0.101
Factor 2	6	1	36	2	1/2	0.025
Factor 3	1/6	1/36	1	1/36	1/36	0.81
Factor 4	1/8	1/2	36	1	1/4	0.013
Factor 5	½	2	36	4	1	0.051

- Number of scrum masters was 1 to 4 for small and medium size organization while the large organizations have 15 scrum masters.
- Education profile of the respondent profile shows that 53% of them have engineering degree, 35% of them are MBA, and 12% are science graduates.
- About 65% of the respondents had 1-5 years of work experience, and the remaining 35% had 5+ years of experience respectively. There were no respondents with less than 1 year of experience.
- Of the represented projects, 65% of them are web and windows-related, 18% of them are for new product development, and the remaining 17% were quality assurance projects.
- Scopes and change of objectives are common in software projects. 53% of the respondents reported 20-40% change while a small percentage (6%) them reported more than 40-60% change. About 41% of the respondents reported 0-20% change in objectives.
- Duration of the projects average around 20weeks.

Although we asked all the respondents to participate in this research method, for simplicity and explanation purpose of our research method, let us consider assessments from two individuals A and B. We asked them to assess three projects each using their own subjective assessments of the same criteria (Tables 1 and 2). Eigenvector values are calculated using Expert Choice software.

Individuals A and B were asked to evaluate three projects (different for each individual) each using both the criteria assessments shown in Tables 1 and 2 respectively. Detailed project assessments are provided in Appendix.

Table 1: Sample data from A

Table 2: Sample data from B

Using Expert choice, we determined the global assessment of the project sets for these two individuals. We call this straight assessment. Using the criteria evaluation of individual A with the project assessment of individual B (and vice versa), we found the corresponding priority vector of the alternatives. We call it reciprocal assessment (Tables 3 and 4).

Factor	Scrum Process Understanding / compliance (Factor 1)	Clarity of Scrum Project i.e. roles & responsibilities (Factor 2)	Effectiveness of Scrum Master (Factor 3)	Degree-Product Owner involvement (Factor 4)	Team collaborative environment (Factor 5)	Eigenvector
Factor 1	1	1/4	1/6	2	6	0.085
Factor 2	4	1	2/3	8	24	0.414
Factor 3	6	3/2	1	12	36	0.444
Factor 4	1/2	1/8	1/12	1	3	0.043
Factor 5	1/6	1/24	1/36	1/3	1	0.014

Table 3: Individual A Project Assessment

Straight	Reciproc
0.55100	0.36323
0.44166	0.42148
0.232336	0.215284

Straight	Reciprocal
0.287501	0.307523
0.523832	0.639519
0.190292	0.283669

Table 4: Individual B Project Assessment

The ranking of projects for individual A has changed whereas it has not changed for individual B.

The complete research data (collected from 17 individuals) for straight and reciprocal assessments is shown in Table 5. The reciprocal assessment is evaluated by using the median value of the 17 individuals.

Project / Sample no.	Project 1		Project 2		Project 3	
	Straight Assessment	Reciprocal Assessment with Median	Straight Assessment	Reciprocal Assessment with Median	Straight Assessment	Reciprocal Assessment with Median
1	0.518	0.404	0.314	0.368	0.168	0.228
2	0.275	0.435	0.532	0.401	0.193	0.185

3	0.656	0.623	0.132	0.152	0.211	0.225
4	0.541	0.497	0.217	0.275	0.242	0.228
5	0.591	0.590	0.166	0.193	0.243	0.218
6	0.737	0.743	0.141	0.135	0.122	0.122
7	0.763	0.768	0.11	0.110	0.127	0.122
8	0.708	0.720	0.118	0.120	0.174	0.160
9	0.62	0.623	0.154	0.152	0.226	0.225
10	0.414	0.455	0.377	0.352	0.209	0.193
11	0.686	0.589	0.141	0.200	0.173	0.211
12	0.368	0.515	0.307	0.238	0.325	0.248
13	0.719	0.376	0.129	0.323	0.152	0.300
14	0.58	0.537	0.241	0.281	0.179	0.182
15	0.595	0.506	0.202	0.239	0.203	0.255
16	0.455	0.367	0.232	0.333	0.313	0.300
17	0.612	0.612	0.181	0.174	0.207	0.214

Table 5: Project evaluation using straight and reciprocal (with median) evaluations

Based on two individual assessments (Tables 3 and 4), the following questions come to mind:

1. Under what conditions does the ranking of the alternatives remain the same?
2. In a group scenario, how do we aggregate multiple assessments?

To address the first question, we examined the root mean squared (RMS) differences between the criteria eigenvector values. Our hypothesis is that the priority ranking in reciprocal assessments does not change for low RMS values (Table 6).

Sample	Priority Change with Median	RMS Value	Comment on RMS value	Hypothesis validity
1	No	0.253	Low	Yes
2	Yes	0.275	High	Yes
3	No	0.266	High	No
4	Yes	0.200	Low	No
5	No	0.323	High	No
6	No	0.241	Low	Yes
7	No	0.161	Low	Yes
8	No	0.320	High	No
9	No	0.258	High	No
10	No	0.307	High	No
11	No	0.238	High	No
12	No	0.191	Low	Yes
13	Yes	0.285	High	Yes
14	No	0.259	High	No
15	No	0.177	Low	Yes
16	Yes	0.289	High	Yes
17	No	0.246	Low	Yes

Table 6: Results of reciprocal assessments with median

We used RMS value of 0.258 (median of 17 values) as the threshold to differentiate between low (less than 0.258) and high (greater than 0.258). From Table 6, Hypothesis is valid in 9 out of 17 (53%) instances. This result is same as a random guess.

Our hypothesis that, high RMS differences in criteria assessment would alter project priority, is <u>not</u> validated. Further investigation is required to understand what other measures in conjunction with RMS differences may be important.

To address the second question above, we looked at the geometric mean or median as an objective indicator for the reciprocal assessments (aggregating group choices). In aggregating group preferences, Lai (2002) suggests the use of the Geometric Mean.

From Table 7, the Median seems to preserve the differentiation between the various elements of the criteria eigenvector. For the Geometric mean, Criteria 2,3,4 and 5 – all have approximately the same weight of 16.3%-19.2%

Factor	Scrum Process Understanding /compliance (Factor 1)	Clarity of Scrum Project i.e. roles & responsibilities (Factor 2)	Effectiveness of Scrum Master (Factor 3)	Degree-Product Owner involvement (Factor 4)	Team collaborative environment (Factor 5)
Geometric Mean	0.305	0.163	0.176	0.165	0.192

Median	0.163	0.249	0.319	0.072	0.195

Table 7: Mean and Median values for each Factor

The evaluation of the reciprocal assessments with the Geometric Mean is constructed, Table 8 and Table-9, in the same way as was done for the assessments using the Median in Table 5 and Table 6.

Project / Sample no.	Project 1		Project 2		Project 3	
	Straight Assessment	Reciprocal Assessment with Geometric Mean	Straight Assessment	Reciprocal Assessment with Geometric Mean	Straight Assessment	Reciprocal Assessment with Geometric Mean
1	0.518	0.442	0.314	0.334	0.168	0.224
2	0.275	0.356	0.532	0.399	0.193	0.245
3	0.656	0.542	0.132	0.188	0.211	0.271
4	0.541	0.492	0.217	0.284	0.242	0.224
5	0.591	0.534	0.166	0.230	0.243	0.236
6	0.737	0.657	0.141	0.173	0.122	0.170
7	0.763	0.673	0.11	0.155	0.127	0.172
8	0.708	0.628	0.118	0.167	0.174	0.204
9	0.62	0.542	0.154	0.188	0.226	0.271
10	0.414	0.481	0.377	0.313	0.209	0.206
11	0.686	0.623	0.141	0.182	0.173	0.195
12	0.368	0.358	0.307	0.319	0.325	0.323
13	0.719	0.329	0.129	0.360	0.152	0.311
14	0.58	0.545	0.241	0.272	0.179	0.183
15	0.595	0.512	0.202	0.207	0.203	0.280
16	0.455	0.402	0.232	0.268	0.313	0.330
17	0.612	0.555	0.181	0.217	0.207	0.228

Table 8: Project evaluation using straight and reciprocal (with geometric mean) evaluations

Sample	Priority Change With Geometric Mean	RMS Value	Comment on RMS value	Hypothesis validity
1	No	0.318	High	No
2	No	0.214	Low	Yes
3	No	0.221	High	No
4	Yes	0.067	Low	No
5	No	0.239	High	No
6	No	0.174	Low	Yes
7	No	0.226	High	No
8	No	0.300	High	No

9	No	0.239	High	No
10	No	0.148	Low	Yes
11	No	0.130	Low	Yes
12	No	0.220	High	No
13	Yes	0.300	High	Yes
14	No	0.208	Low	Yes
15	No	0.171	Low	Yes
16	No	0.238	High	No
17	No	0.141	Low	Yes

Table 9: Results of reciprocal assessments with geometric mean

We used RMS value of 0.220 (median of 17 values) as the threshold to differentiate between low (less than 0.220) and high (greater than 0.220).

Hypothesis is valid in 8 out 17 (47%) instances. This result is same as random guess.

6. Conclusion

The process by which reciprocal assessments have been derived provide for a more rational way of understanding group responses and each other's rationale and we feel, will aid team processes such as Delphi. Discussions on delivering performances can now be standardized. Such a method also finds utility in finding the best projects or poorly managed projects. This methods aids in developing lessons learnt and best practices.

While reciprocal assessment is a useful tool, the method used to create it via Geometric Mean, Median etc. needs a more thorough evaluation. It is also not clear what is a suitable measure for aggregating group responses. From our effort above, neither the Median nor the Geometric Mean is suitable for aggregating responses from a group.

The measure used to identify whether two judgments are agreeable to one another or "close enough" to each other needs to be defined more clearly. We find that RMS values of criteria differences is not giving us a good measure, during reciprocal evaluations, of assessing whether project priority assessment will change or not.

Also, for reciprocal assessments, it is clear that RMS measure is not significant and a weighted measure (with weights arising out alternatives assessment) should be investigated. We feel that the definition of RMS threshold needs a more in-depth look and understanding. Our definition of Low and High range (using median, mean) is also ad hoc. Are there other *a priori* or *a posteriori* estimators that will be useful in the group aggregation process similar to those raised (in a different context) by the first author [Hoppe et al., 2006]

The problem considered here is more complicated than that needs addressing in the first place – i.e., given many criteria assessments (with only one set of alternatives and alternatives assessment); how do we define closeness of the assessments and what can be considered as outliers. Unlike the classic definition and use of outliers, in this case we have to compare vectors (criteria eigenvectors).

The subjectivity issue is a little more complicated as criteria eigenvectors are derived quantities and the fundamental set of quantities to be considered are the matrix elements of pair-wise comparisons. This is harder to deal with than the problem we considered with vectors of criteria weights. The subjectivity gets more confounding if there in-consistent data sets raising the larger issue of how to collect data without explaining the analytical hierarchy technique to the respondents.

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7. Limitations and Future Scope

As discussed, we have a limitation for the criteria table we used four sets of pair-wise comparison data and two for each of the project judgments to derive a consistent set of all pair-wise comparisons. So, in future surveys we should require the use of numbers instead of using Likert-type scale. Also we hope to develop a mechanism (via surveys) for deriving consistent pair-wise comparison.

Even though the project managers were asked to evaluate five criteria, we observed that only three criteria are being adequately considered. Weightage of two factors are in the range of 0-10% wherein the pair-wise comparison numbers are very high (12,24,36 etc.)

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9. Appendix

The following four tables give the raw data and calculations for the two individuals (other 15 respondents are omitted for brevity) – (1) pair-wise criteria comparisons (2) pair-wise comparison of alternatives for each criteria (3), (4) are project assessments for each criteria.

Pair-wise Comparison between each factor		Individual A	Individual B
Scrum process under-standing/ compliance	Clarity of Scrum Projects i.e. roles & responsibilities	4	1/4
	Effectiveness of Scrum Master	1/8	1/6
	Customer – Degree of Product Owner involvement	8	2
	Team collaborative environment	2	6
Clarity of Scrum Projects i.e. roles and responsibilities	Effectiveness of Scrum Master	1/32	2/3
	Customer – Degree of Product Owner involvement	2	8
	Team collaborative environment	1/2	24
Effectiveness of Scrum Master	Customer – Degree of Product Owner involvement	64	12
	Team collaborative environment	16	36
Customer – Degree of Product Owner involvement	Team collaborative environment	1/4	3

Table 9: Pair-wise criteria assessments

Pair-wise comparison - each project / each factor			Individual A	Individual B
Factor	Project			
Scrum process under-standing/compliance (F1)	P1	P2	1/4	4
		P3	2	4
	P2	P3	2	1
Clarity of Scrum Projects i.e. roles and responsibilities (F2)	P1	P2	1/4	6
		P3	1/2	2
	P2	P3	1/2	1/3
Effectiveness of Scrum Master (F3)	P1	P2	2	1/4
		P3	4	1/2
	P2	P3	2	1/2
Customer – Degree of Product Owner involvement (F4)	P1	P2	4	6
		P3	1/6	1/6
	P2	P3	2/3	1
Team collaborative environment (F5)	P1	P2	4	4
		P3	1/2	4
	P2	P3	2	1

Table 10: Pair-wise Project assessments

\Criteria	F1	F2	F3	F4	F5	Overall / Cumulative
Project 1	0.143	0.143	0.571	0.706	0.571	0.518
Project 2	0.571	0.571	0.286	0.176	0.143	0.314
Project 3	0.286	0.286	0.143	0.118	0.286	0.168

Table 11: Project assessments for each criteria for Individual A

\Criteria	F1	F2	F3	F4	F5	Overall / Cumulative
Project 1	0.667	0.3	0.143	0.75	0.776	0.275
Project 2	0.167	0.6	0.571	0.125	0.167	0.532
Project 3	0.167	0.1	0.286	0.125	0.167	0.193

Table 12: Project assessments for each criteria for Individual B