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Procurement Maturity determination using AHP and Fuzzy AHP Method – a comparative Study

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Abstract:
Maturity is a concerned area of all professional practice. Procurement maturity is an area of less discussed and less renowned but truly important for efficient procurement practice for developing countries where national growth depends on governments' large procurement cases vastly as significant part of national budget is allocated for development work where procurement holds the major portion of monetary fund. A grading scale is proposed combining few existing scales removing their discrepancies. Also, AHP (Analytical Hierarchical Process) and Fuzzy AHP methods have been applied to determine the procurement maturity. Obtained numeric result is placed in proposed grading scale to indicate the maturity level in letter grade. Results of both the method have been compared.

Key Word*: Procurement, Maturity, Fuzzy, AHP, Fuzzy AHP*

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I. Introduction

How does a procurement case be assessed what level of quality in practice achieved or maintained? The answer is to determine the assessment criteria first and assess the quality level of practice as profession and judgment is to be carried out according to desired expectation. The determinants for judgment a procurement practice have been defined by Stephen Guth (2010) [1] and maturity scale is also introduced by both Guth (2010) and Duinkerken et. al. (2008) [2]. But there is no demonstration in determination of procurement maturity in professional practice. There is thirst in application of mathematical models in determining procurement maturity. The aim of this work is to formulate a mathematical outline using available methods, determinants and scale and illustrate considering a real case to determine procurement maturity level. Moreover, an existing maturity scale is to be evaluated and propose a new scale removing the discrepancies. Also, it is to compare results of applying AHP (Analytical Hierarchical Process) and Fuzzy AHP method in determining procurement maturity.

II. Background

According to Stephen Guth (2010), procurement system's maturity is measured with respect to a best practice benchmark. Such benchmark is not an arbitrary consideration rather 60 best practices have been identified among many cases which all are set as the upper limit of quality of procurement service or benchmark level and a test case is measured with the gap analysis between the ceiling of best case and status level of test case [1]. Though Stephen Guth has shown the measurement process quite clearly with benchmarking, the test cases are measured on the basis or rating of auditors for quality judgment on which the rating score is further calculated. The calculation model is further necessary to be grabbed.

It is the motivation to find the procurement maturity in case of absence of best practice cases and such benchmarks. AHP and Fuzzy AHP are quite suitable method for judgment of a procurement case to determine its quality or professional maturity level in case of absence of any particular maturity level defined based on best practices. An important suggestion of Stephen Guth is that procurement maturity is highly obtained by establishing a separate department for procurement works in procuring agency organization and dedicated procurement professionals working in such area [1]. The method we are to discuss in this paper will help the professionals and make this process much simpler, clear and systematic approach to implement.

III. PMM and Framework

PMM stands for Procurement Maturity Model. In Table no 1, a list of determinant for calculation of procurement maturity has been shown. This list is defined by Stephen Guth (2010) and also a maturity determination scale has been presented by him that consists of six different levels of maturity which are

Inhibiting & Performing, Enabling & Optimizing, Best in Class & World Class [1]. The scale is shown in Table no 2. The problem exists in the scale interpretation in Table no 2 is that different maturity levels are defined in successive pairs and the requirement criteria are defined for each pair to achieve the desired level of practice. Each level of maturity is necessary to be uniquely defined with requirement criteria to avoid ambiguities. Each and every level of maturity is also needed to have numerical values assigned for the ease of maturity calculation.

According to Wilco Van Duinkerken et. al (2008), Procurement Maturity Framework (PMF) describes the assessment level of a procurement method where it begins from Transaction level, Commercial level, Purchasing level, Internal level, External level up to Value chain level [2]. The levels are described in Table no 3. If two scales in Table no 2 and Table no 3 are compared, it is seen that both the scales are six level maturity scale and the requirement criteria are quite close for successive levels of maturity. For example, 'Suppliers are considered valuable integrated resources for the organization' in Wilco Van's scale [2] in Table no 3 is a pretty close requirement of 'Organization looks beyond itself (Supplier Delivery, Rationalization and Development)' in Stephen Guth's scale [1] in Table no 2 for the levels of 'External Integration' and 'Best in Class & World Class' respectively. But the ambiguity remains whether the requirement in Guth's scale is defined for 'Best in Class' or 'World Class' level specifically and similarly for others. In this context, it is a matter to be to try to merge both the scale and assign the numeric for each every level so that value can be computed using mathematical model to determine the maturity level. The proposed scale shows the letter grading of the maturity level found in any real case like Level A, Level B, Level C and so on as shown in Table no 4.

Table no 1: Stephen Guth's determinants list [1]

Major Area of Procurement Maturity	Sub Areas of Procurement Maturity
Customer	Engagement(EGN), Procurement Instruction(PIS), Relationship Management(RMG), Satisfaction(STF), Status Reporting(SRT)
Organization	Best Practice(BPC), Business Plan(BPN), Executive Support(EXS), Mission Statement(MSN), Strategic Plan(SPN), Structure(STR), Vision Statement(VSN)
Policy	Approval authority levels(AUL), Business Continuity Plan(BCP), Delegation of spend(DSP), Procurement authority(PAT), Procurement policy(PPY), Procurement standards(PSD), Record retention(RRN)
Process	Audit(AUD), Competitive bidding plan(CBP), Cost reduction plans(CRP), Forecast(FRC), Negotiation planning(NGP), Purchase order generation(POG), Spend profile(SPL).
Staff	Certification(CRT), Commodity training(CTR), Customer engagement(CEG), Employee engagement(EEG), Job qualification(JQF), Performance Management(PMG), Performance objectives(PFO), Procurement Training(PRT), Training Plan(TRP)
Tools	Contract approval workflow automation(CWA), Contract labor sourcing system(CSS), Contract management system(CMS), Contract templates(CTL), eRFX(RFX) External Website(EXW), P-Cards(PCD), Procure-to-Process(PPO), Requisition(RQS), Reverse auctions(RVA), RFX templates(RFT), Third party research(TPR), Vendor profile system(VPS), Vendor relationship management system(VRM)
Value	Contract disputes(CDS), Contract risk level(Rv), Contract Template Ratio(CRO), Contract turnaround time(CTT), Cost savings(CVS), RFX turnaround time(RTT)
Vendors	Approved vendor list(AVL), Measurement and Matrices(MMS), Vendor categorization(VCN), Vendor qualification(VQN), Vendor Rationalization(VRN), Vendor Recognition(VRG)

Table no 2: Stephen Guth's maturity scale's interpretation [1]

Maturity Level	Interpretations
World Class	-Procurement is Strategic, Core Competency -Proficient at Expected Business Practices (High degree of Customer and Supplier Satisfaction) -Staffed with High Qualified (e.g. Degreed and Certified) Professionals -High degree of Automation -Matrix Driven -Organization looks beyond itself (e.g. Supplier Delivery, Rationalization and Development)
Best in Class	
Optimizing	-Procurement seen as 'Value-add' function -Some executive support and Investment -Customers and Suppliers satisfied for the most part -Employees Engaged (Some view Procurement as a 'Job') -Some pursuit of Best Practices
Enabling	
Performing	-Procurement an Afterthought, that a Core Corruptency -Customers and Suppliers Avoid interaction -Employees Activity Disengaged
Inhibiting	

Table no 3: e-Procurement maturity framework defined by Wilco Van [2]

Maturity Level	Interpretation
Value chain integration	The procurement department is contributing to the effectiveness of the entire consumer supply chain
External integration	Suppliers and considered valuable integrated resources for the organization
Internal integration	The procurement department is considered as a strategic internally integrated part of the overall organization
Purchasing coordination	Basic sourcing and purchasing optimization is in place within the procurement department
Commercial orientation	Mainly Cost oriented purchasing
Transaction orientation	No procurement strategy, procurement is just acting on purchasing requests from the rest of the organization

Table no 4: Matching between Stephen Guth and Wilco Van maturity levels and proposed new maturity grade

Maturity Grade	Scale Value	Maturity Levels	Maturity level requirement specifications
A	6.68~8.00	World Class/Value Chain integration	-The procurement department is contributing to the effectiveness of the entire consumer supply chain by practicing procurement as strategic goal for business proficiency with core competency,
B	5.34~6.67	Best in Class/External integration	-Staffed with High Qualified (e.g. Degreed and Certified) Professionals -High degree of Automation -Matrix Driven -Organization looks beyond itself (e.g. Supplier Delivery, Rationalization and Development) - Suppliers are considered valuable integrated resources for the organization
C	4.01~5.33	Optimizing/ Internal Integration	-The procurement department is considered as a strategic internally integrated part of the overall organization -Some pursuit of Best Practices -Customers and Suppliers satisfied for the most part
D	2.68~4.00	Enabling/ Purchasing orientation	-Procurement seen as 'Value-add' function -Some executive support and Investment -Employees Engaged (Some view Procurement as a 'Job')
E	0.00~2.67	Inhibiting/ Performing/ Transaction/ Commercial orientation	-Mainly Cost oriented purchasing - No procurement strategy, procurement is just acting on purchasing requests from the rest of the organization -Procurement an Afterthought, that a Core Corruptency -Customers and Suppliers Avoid interaction -Employees Activity Disengaged

IV. AHP and Fuzzy AHP Method

AHP and Fuzzy AHP methods are useful tool for decision making when multiple criteria and multiple solution alternatives are present in a case. A pair wise comparison matrix is firstly formed if we have n numbers of criteria are available as in Table no 5 and choice of preferences are substituted in the matrix. The Table no 5 matrix is written as equation in eq (1). The matrix in normalized dividing each element of the matrix by column

sum, then the new matrix N is formed and taking the row averages of N matrix, we get w_i values of W row matrix where the final result is obtained by taking the highest values of w_i. This is all about AHP method discussed by Taha [3]. Both AHP and Fuzzy AHP deal with the stochastic data. Fuzzy logic allows quantification of vagueness and produce decision result. Fuzzy AHP is also called Fuzzy MPDM (Multi person decision making) or more specifically MPPC (Multi person preference criteria). After getting the fuzzy ratings, a pair wise comparison matrix like eq (1) is formed too and eq (5) does the first normalization. After first normalization, the minimum values of each row of first normalized matrix is extracted to form a new row matrix using eq (6) and finally highest value among the minimum values of each row as in eq (7) is the result determined by this method [4,5].

Table no 5: Fuzzy pair wise decision criteria evaluation matrix for n criteria

	C1	C2	… … …	Cn
C1	a_{11}	a12	… … …	a_{1n}
C2	a_{21}	a22	… … …	a_{2n}
. . .	. .	. .	. .	. .
Cn	a_{n1}	an2	… … …	A_{nn}

$$A = \begin{pmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & \cdots & \vdots \\ a_{n1} & a_{n2} & & a_{nn} \end{pmatrix} \ldots \ldots \ldots \quad (1)$$

$$N = \begin{pmatrix} \frac{a_{11}}{\sum_{i=1}^{n} a_{i1}} & \frac{a_{12}}{\sum_{i=1}^{n} a_{i2}} & \cdots & \frac{a_{1n}}{\sum_{i=1}^{n} a_{in}} \\ \frac{a_{21}}{\sum_{i=1}^{n} a_{i1}} & \frac{a_{22}}{\sum_{i=1}^{n} a_{i2}} & \cdots & \frac{a_{2n}}{\sum_{i=1}^{n} a_{in}} \\ \vdots & \vdots & & \vdots \\ \frac{a_{n1}}{\sum_{i=1}^{n} a_{i1}} & \frac{a_{n2}}{\sum_{i=1}^{n} a_{i2}} & \cdots & \frac{a_{nn}}{\sum_{i=1}^{n} a_{in}} \end{pmatrix} = \begin{pmatrix} N_{11} & N_{12} & \cdots & N_{1n} \\ N_{21} & N_{22} & \cdots & N_{2n} \\ \vdots & \vdots & \cdots & \vdots \\ N_{n1} & N_{n2} & & N_{nn} \end{pmatrix} \ldots \ldots \ldots \quad (2)$$

$$W = \begin{pmatrix} \frac{N_{11}+N_{12} \ldots N_{1n}}{n} \\ \frac{N_{21}+N_{22} \ldots N_{2n}}{n} \\ \vdots \\ \frac{N_{n1}+N_{n2} \ldots N_{nn}}{n} \end{pmatrix} = \begin{pmatrix} w_1 \\ w_2 \\ \vdots \\ w_n \end{pmatrix} \ldots \ldots \ldots \quad (3)$$

$$R = max(w_i) \ldots \ldots \ldots \quad (4)$$

$$f(x_i, x_j) = \frac{f(x_i, x_j)}{max[f(x_i, x_j), f(x_j, x_i)]} \ldots \ldots \ldots \quad (5)$$

$$f^{/}(X_k) = min(X_i) \ldots \ldots \ldots \quad (6)$$

$$R = max[f^{/}(X_k)] \ldots \ldots \ldots \quad (7)$$

V. Illustrative Example

Whatever we use the method either AHP or Fuzzy AHP, the assessors' ratings are substituted in the A matrix (eq. 1) using the linguistics of Table no 6 with which we have applied the technique of AHP and Fuzzy AHP in order to determine maturity level. In this Illustrative Example, each major area of concentration is

measured by a fuzzy normalized rating value through comparison matrix of sub-criteria and normalized using the eq (2) and (3) for AHP normalization and eq (4) for determination of result. Beside this, the same comparison matrix is normalized using eq (5) and (6) for Fuzzy AHP normalization and eq (7) gives the result.

The normalized rating values of all major areas like 'Customer', 'Organization', 'Policy', 'Process', 'Staff', 'Tools', 'Value' and 'Vendors' are summed up and summation result is positioned into the scale in Table no 4 and letter grade is determined.

'Customer' is a major area of maturity concern where the sub criteria are Engagement (EGN), Procurement Instruction (PIS), Relationship Management (RMG), Satisfaction (STF), Status Reporting (SRT). Using these sub criteria, a pair wise comparison matrix is formed in Table no 7 using the linguistics in Table no 6. Table no 7 holds Fuzzy ratings given by an assessor in a test case which is normalized for Fuzzy normalization. Table no 8 holds the normalized values and row matrix of minimum row values is obtained (0.5, 0.38, 0.13, 1.0, 0.33) where the highest resulting value of the minimum row values is 1.0. Beside this result, we have AHP normalization values in Table no 9 of the same matrix of Table no7 dividing each element by each respective column sum and taking the row averages of normalized matrix, we get (0.211 0.193 0.116 0.250 0.230). Therefore, AHP result determines 0.25 as practice level in the area of 'Customer' of procurement maturity determinants. For rest of the maturity determining attributes from 'Organization' to 'Vendors', the same above process is repeatedly applied and normalizations are shown in the tables from Table no 10 to Table no30 respectively. And the row matrices generated for each attribute for each Fuzzy AHP and AHP normalization are summarized in Table no 31 from which we have got the resulting scores listed in Table no 32. The total scores determined for Fuzzy AHP method is 5.09 and for AHP method is 1.41 that indicates maturity grade C and E respectively matching with the scale in Table no 32.

Table no 6: Suggested numbers for maturity grading [4]

$f(x_i, x_j)$	Maturity weight x_i of with respect to x_j
1	Low maturity
3	Moderate maturity
5	High maturity
7	Very high maturity
9	Extra high maturity
2,4,6,8	Intermediate values between levels

Table no 7: Fuzzy rating of procurement maturity identifier 'Customer'

	ENG	PIS	RMG	STF	SRT
ENG	1	5	2	5	7
PIS	5	1	6	3	3
RMG	4	4	1	1	1
STF	6	8	1	1	8
SRT	3	1	8	8	1

Table no 8: Normalized values of Table 7 matrix of Fuzzy Normalization

	ENG	PIS	RMG	STF	SRT
ENG	1.0	1.0	0.5	0.83	1.0
PIS	1.0	1.0	1.0	0.38	1.0
RMG	1.0	0.67	1.0	1.0	0.12
STF	1.0	1.0	1.0	1.0	0.12
SRT	0.43	0.33	1.0	1.0	1.0

Table no 9: Normalized values of Table 7 matrix of AHP Normalization

	ENG	PIS	RMG	STF	SRT
ENG	0.053	0.263	0.111	0.278	0.350
PIS	0.263	0.053	0.333	0.167	0.150
RMG	0.211	0.211	0.056	0.056	0.050
STF	0.316	0.421	0.056	0.056	0.400
SRT	0.158	0.053	0.444	0.444	0.050

Table no 10: Fuzzy rating of procurement maturity identifier 'Organization'

	BPC	BPN	EXS	MSN	SPN	STR	VSN
BPC	1	4	2	5	1	2	5
BPN	5	1	6	7	3	5	8
EXS	4	4	1	1	5	3	1
MSN	6	8	1	1	5	1	3
SPN	3	1	8	8	1	6	4
STR	5	6	6	7	3	1	9
VSN	4	4	3	1	5	4	1

Table no 11: Normalized values of Table 11 matrix of Fuzzy Normalization

	BPC	BPN	EXS	MSN	SPN	STR	VSN
BPC	1.0	0.8	0.5	0.83	0.33	0.4	1.0
BPN	1.0	1.0	1.0	0.88	1.0	0.83	1.0
EXS	1.0	0.67	1.0	1.0	0.62	0.5	0.33
MSN	1.0	1.0	1.0	1.0	0.62	0.14	1.0
SPN	1.0	0.33	1.0	1.0	1.0	1.0	0.8
STR	1.0	1.0	1.0	1.0	0.5	1.0	1.0
VSN	0.8	0.5	1.0	0.33	1.0	0.44	1.0

Table no 12: Normalized values of Table 11 matrix of AHP Normalization

	BPC	BPN	EXS	MSN	SPN	STR	VSN
BPC	0.036	0.143	0.074	0.167	0.043	0.091	0.161
BPN	0.179	0.036	0.222	0.233	0.130	0.227	0.258
EXS	0.143	0.143	0.037	0.033	0.217	0.136	0.032
MSN	0.214	0.286	0.037	0.033	0.217	0.045	0.097
SPN	0.107	0.036	0.296	0.267	0.043	0.273	0.129
STR	0.179	0.214	0.222	0.233	0.130	0.045	0.290
VSN	0.143	0.143	0.111	0.033	0.217	0.182	0.032

Table no 13: Fuzzy rating of procurement maturity identifier 'Policy'

	AUL	BCP	DSP	PAT	PPY	PSD	RRN
AUL	1	3	1	7	2	3	6
BCP	7	1	7	8	2	3	7
DSP	4	1	1	3	5	4	2
PAT	1	7	3	1	3	5	4
PPY	8	1	7	7	1	8	7
PSD	5	5	6	6	1	1	8
RRN	3	4	8	8	8	1	1

Table no 14: Normalized values of Table 13 matrix of Fuzzy Normalization

	AUL	BCP	DSP	PAT	PPY	PSD	RRN
AUL	1.0	0.43	0.25	1.0	0.25	0.6	1.0
BCP	1.0	1.0	1.0	1.0	1.0	0.6	1.0
DSP	1.0	0.14	1.0	1.0	0.71	0.67	0.25
PAT	1.0	0.88	1.0	1.0	0.43	0.83	0.5
PPY	1.0	0.5	1.0	1.0	1.0	1.0	0.88
PSD	1.0	1.0	1.0	1.0	0.12	1.0	1.0
RRN	0.5	0.57	1.0	1.0	1.0	0.12	1.0

Table no 15: Normalized values of Table 13 of AHP Normalization

	AUL	BCP	DSP	PAT	PPY	PSD	RRN
AUL	0.034	0.136	0.03	0.175	0.091	0.12	0.171
BCP	0.241	0.045	0.212	0.2	0.091	0.12	0.2
DSP	0.138	0.045	0.03	0.075	0.227	0.16	0.057
PAT	0.034	0.318	0.091	0.025	0.136	0.2	0.114

PPY	0.276	0.045	0.212	0.175	0.045	0.32	0.2
PSD	0.172	0.227	0.182	0.15	0.045	0.04	0.229
RRN	0.103	0.182	0.242	0.2	0.364	0.04	0.029

Table no 16: Fuzzy rating of procurement maturity identifier 'Process'

	AUD	CBP	CRP	FRC	NGP	POG	SPL
AUD	1	4	6	9	3	2	7
CBP	9	1	7	1	3	3	6
CRP	8	2	1	4	2	4	3
FRC	4	5	1	1	5	5	5
NGP	4	2	5	6	1	7	8
POG	1	6	7	6	9	1	1
SPL	7	3	7	5	1	2	1

Table no 17: Normalized values of Table 16 matrix of Fuzzy Normalization

	AUD	CBP	CRP	FRC	NGP	POG	SPL
AUD	1.0	0.44	0.75	1.0	0.75	1.0	1.0
CBP	1.0	1.0	1.0	0.2	1.0	0.5	1.0
CRP	1.0	0.29	1.0	1.0	0.4	0.57	0.43
FRC	0.44	1.0	0.25	1.0	0.83	0.83	1.0
NGP	1.0	0.67	1.0	1.0	1.0	0.78	1.0
POG	0.5	1.0	1.0	1.0	1.0	1.0	0.5
SPL	1.0	0.5	1.0	1.0	0.12	1.0	1.0

Table no 18: Normalized values of Table 16 matrix of AHP Normalization

	AUD	CBP	CRP	FRC	NGP	POG	SPL
AUD	0.029	0.174	0.176	0.281	0.125	0.083	0.226
CBP	0.265	0.043	0.206	0.031	0.125	0.125	0.194
CRP	0.235	0.087	0.029	0.125	0.083	0.167	0.097
FRC	0.118	0.217	0.029	0.031	0.208	0.208	0.161
NGP	0.118	0.087	0.147	0.188	0.042	0.292	0.258
POG	0.029	0.261	0.206	0.188	0.375	0.042	0.032
SPL	0.206	0.13	0.206	0.156	0.042	0.083	0.032

Table no 19: Fuzzy rating of procurement maturity identifier 'Staff'

	CRT	CTR	CEG	EEG	JQF	MPG	PFO	PRT	TRP
CRT	1	3	7	5	1	2	6	3	7
CTR	4	1	5	6	8	7	8	5	1
CEG	8	2	1	4	2	4	3	1	9
EEG	4	5	1	1	5	5	5	4	5
JQF	5	5	3	1	1	8	4	7	6
MGP	1	6	7	6	9	1	1	7	2
PFO	9	9	7	1	3	3	1	6	2
PRT	1	4	6	9	3	2	7	1	3
TRP	4	3	6	7	8	3	6	4	1

Table no 20: Normalized values of Table 19 matrix of Fuzzy Normalization

	CRT	CTR	CEG	EEG	JQF	MPG	PFO	PRT	TRP
CRT	1.0	0.75	0.88	1.0	0.2	1.0	0.67	1.0	1.0
CTR	1.0	1.0	1.0	1.0	1.0	1.0	0.89	1.0	0.33
CEG	1.0	0.4	1.0	1.0	0.67	0.57	0.43	0.17	1.0
EEG	0.8	0.83	0.25	1.0	1.0	0.83	1.0	0.44	0.71
JQF	1.0	0.62	1.0	0.2	1.0	0.89	1.0	1.0	0.75
MGP	0.5	0.86	1.0	1.0	1.0	1.0	0.33	1.0	0.67
PFO	1.0	1.0	1.0	0.2	0.75	1.0	1.0	0.86	0.33
PRT	0.33	0.8	1.0	1.0	0.43	0.29	1.0	1.0	0.75
TRP	0.57	1.0	0.67	1.0	1.0	1.0	1.0	1.0	1.0

Table no 21: Normalized values of Table 19 of AHP Normalization

	CRT	CTR	CEG	EEG	JQF	MPG	PFO	PRT	TRP
CRT	0.027	0.079	0.163	0.125	0.025	0.057	0.146	0.079	0.194
CTR	0.108	0.026	0.116	0.15	0.2	0.2	0.195	0.132	0.028
CEG	0.216	0.053	0.023	0.1	0.05	0.114	0.073	0.026	0.25
EEG	0.108	0.132	0.023	0.025	0.125	0.143	0.122	0.105	0.139

JQF	0.135	0.132	0.07	0.025	0.025	0.229	0.098	0.184	0.167
MGP	0.027	0.158	0.163	0.15	0.225	0.029	0.024	0.184	0.056
PFO	0.243	0.237	0.163	0.025	0.075	0.086	0.024	0.158	0.056
PRT	0.027	0.105	0.14	0.225	0.075	0.057	0.171	0.026	0.083
TRP	0.108	0.079	0.14	0.175	0.2	0.086	0.146	0.105	0.028

Table no 22: Fuzzy rating of procurement maturity identifier 'Tools'

	CWA	CSS	CMS	CTL	RFX	EXW	PCD	PPO	RQS	RVA	RFT	TPR	VPS	VRM
CWA	1	7	8	4	7	3	7	1	6	7	7	3	7	5
CSS	6	1	9	1	4	2	5	9	9	7	4	2	5	6
CMS	1	3	1	6	8	2	5	1	4	6	8	2	5	4
CTL	9	3	2	1	4	5	1	4	3	6	4	5	1	2
RFX	7	3	7	5	1	2	9	9	1	2	5	5	3	1
EXW	4	2	5	6	8	1	3	3	6	5	1	6	7	6
PCD	8	2	5	4	2	4	1	2	7	2	2	5	4	2
PPO	4	5	1	2	5	5	3	1	5	7	5	1	2	5
RQS	5	5	3	1	7	8	9	3	1	7	4	5	3	2
RVA	4	5	1	2	5	5	5	4	5	1	4	3	1	1
RFT	5	5	3	1	7	8	4	7	6	6	1	1	9	8
TPR	8	2	5	4	2	4	3	3	1	2	5	1	5	7
VPS	2	5	5	5	4	6	9	2	3	1	7	8	1	9
VRM	3	1	8	8	3	5	1	3	3	6	8	2	5	1

Table no 23: Normalized values of Table 22 matrix of Fuzzy Normalization

	CWA	CSS	CMS	CTL	RFX	EXW	PCD	PPO	RQS	RVA	RFT	TPR	VPS	VRM
CWA	1.0	1.0	1.0	0.44	1.0	0.75	0.88	0.25	1.0	1.0	1.0	0.38	1.0	1.0
CSS	0.86	1.0	1.0	0.33	1.0	1.0	1.0	1.0	1.0	1.0	0.8	1.0	1.0	1.0
CMS	0.12	0.33	1.0	1.0	1.0	0.4	1.0	1.0	1.0	1.0	1.0	0.4	1.0	0.5
CTL	1.0	1.0	0.33	1.0	0.86	0.83	0.25	1.0	1.0	1.0	1.0	1.0	0.2	0.25
RFX	1.0	0.75	0.88	1.0	1.0	0.25	1.0	1.0	0.14	0.4	0.71	1.0	0.75	0.33
EXW	1.0	1.0	1.0	1.0	1.0	1.0	0.75	0.6	0.75	1.0	0.12	1.0	1.0	1.0
PCD	1.0	0.4	1.0	1.0	0.22	1.0	1.0	0.67	0.78	0.4	0.5	1.0	0.44	1.0
PPO	1.0	0.56	1.0	0.5	0.56	1.0	1.0	1.0	1.0	1.0	0.71	0.33	1.0	1.0
RQS	0.83	0.56	0.75	0.33	1.0	1.0	1.0	0.6	1.0	1.0	0.67	1.0	1.0	0.67
RVA	0.57	0.71	0.17	0.33	1.0	1.0	1.0	0.57	0.71	1.0	0.67	1.0	1.0	0.17
RFT	0.71	1.0	0.38	0.25	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.2	1.0	1.0
TPR	1.0	1.0	1.0	0.8	0.4	0.67	0.6	1.0	0.2	0.67	1.0	1.0	0.62	1.0
VPS	0.29	1.0	1.0	1.0	1.0	0.86	1.0	1.0	1.0	1.0	0.78	1.0	1.0	0.2
VRM	0.60	0.17	1.0	1.0	1.0	0.83	0.5	0.6	1.0	1.0	1.0	0.29	1.0	1.0

Table no 24: Normalized values of Table 22 matrix of AHP Normalization

	CWA	CSS	CMS	CTL	RFX	EXW	PCD	PPO	RQS	RVA	RFT	TPR	VPS	VRM
CWA	0.015	0.143	0.127	0.08	0.104	0.05	0.108	0.019	0.1	0.108	0.108	0.061	0.121	0.085
CSS	0.09	0.02	0.143	0.02	0.06	0.033	0.077	0.173	0.15	0.108	0.062	0.041	0.086	0.102
CMS	0.015	0.061	0.016	0.12	0.119	0.033	0.077	0.019	0.067	0.092	0.123	0.041	0.086	0.068
CTL	0.134	0.061	0.032	0.02	0.06	0.083	0.015	0.077	0.05	0.092	0.062	0.102	0.017	0.034
RFX	0.104	0.061	0.111	0.1	0.015	0.033	0.138	0.173	0.017	0.031	0.077	0.102	0.052	0.017
EXW	0.06	0.041	0.079	0.12	0.119	0.017	0.046	0.058	0.1	0.077	0.015	0.122	0.121	0.102
PCD	0.119	0.041	0.079	0.08	0.03	0.067	0.015	0.038	0.117	0.031	0.031	0.102	0.069	0.034
PPO	0.06	0.102	0.016	0.04	0.075	0.083	0.046	0.019	0.083	0.108	0.077	0.02	0.034	0.085
RQS	0.075	0.102	0.048	0.02	0.104	0.133	0.138	0.058	0.017	0.108	0.062	0.102	0.052	0.034

RVA	0.06	0.102	0.016	0.04	0.075	0.083	0.077	0.077	0.083	0.015	0.062	0.061	0.017	0.017
RFT	0.075	0.102	0.048	0.02	0.104	0.133	0.062	0.135	0.1	0.092	0.015	0.02	0.155	0.136
TPR	0.119	0.041	0.079	0.08	0.03	0.067	0.046	0.058	0.017	0.031	0.077	0.02	0.086	0.119
VPS	0.03	0.102	0.079	0.1	0.06	0.1	0.138	0.038	0.05	0.015	0.108	0.163	0.017	0.153
VRM	0.045	0.02	0.127	0.16	0.045	0.083	0.015	0.058	0.05	0.092	0.123	0.041	0.086	0.017

Table no 25: Fuzzy rating without numerical equivalence of the Risk Value of identifier 'Value'

	CDS	RV	CRO	CTT	CVS	RTT
CDS	1	2	5	3	4	2
RV	5	1	6	7	3	1
CRO	3	9	1	4	6	4
CTT	7	5	5	1	7	9
CVS	4	3	6	5	1	8
RTT	4	1	3	7	9	1

Table no 26: Normalized values of Table 25 matrix of Fuzzy Normalization

	CDS	RV	CRO	CTT	CVS	RTT
CDS	1.0	0.4	1.0	0.43	1.0	0.5
RV	1.0	1.0	0.67	1.0	1.0	1.0
CRO	0.6	1.0	1.0	0.8	1.0	1.0
CTT	1.0	0.71	1.0	1.0	1.0	1.0
CVS	1.0	1.0	1.0	0.71	1.0	0.89
RTT	1.0	1.0	0.75	0.78	1.0	1.0

Table no 27: Normalized values of Table 25 matrix of AHP Normalization

	CDS	RV	CRO	CTT	CVS	RTT
CDS	0.042	0.095	0.192	0.111	0.133	0.080
RV	0.208	0.048	0.231	0.259	0.100	0.040
CRO	0.125	0.429	0.038	0.148	0.200	0.160
CTT	0.292	0.238	0.192	0.037	0.233	0.360
CVS	0.167	0.143	0.231	0.185	0.033	0.320
RTT	0.167	0.048	0.115	0.259	0.300	0.040

Table no 28: Fuzzy rating of procurement maturity identifier 'Vendors'

	AVL	MMS	VCN	VQN	VRN	VRG
AVL	1	5	4	2	4	3
MMS	5	1	2	5	5	5
VCN	5	3	1	7	8	4
VQN	6	7	6	1	9	1
VRN	9	7	1	3	1	6
VRG	4	6	9	3	2	1

Table no 29: Normalized values of Table 28 matrix of Fuzzy Normalization

	AVL	MMS	VCN	VQN	VRN	VRG
AVL	1.0	1.0	0.8	0.33	0.44	0.75
MMS	1.0	1.0	0.67	0.71	0.71	0.83
VCN	1.0	1.0	1.0	1.0	1.0	0.44
VQN	1.0	1.0	0.86	1.0	1.0	0.33
VRN	1.0	1.0	0.12	0.33	1.0	1.0
VRG	1.0	1.0	1.0	1.0	0.33	1.0

Table no 30: Normalized values of Table 28 matrix of AHP Normalization

	AVL	MMS	VCN	VQN	VRN	VRG
AVL	0.033	0.172	0.174	0.095	0.138	0.15
MMS	0.167	0.034	0.087	0.238	0.172	0.25
VCN	0.167	0.103	0.043	0.333	0.276	0.2
VQN	0.2	0.241	0.261	0.048	0.31	0.05
VRN	0.3	0.241	0.043	0.143	0.034	0.3
VRG	0.133	0.207	0.391	0.143	0.069	0.05

Table no 31: Row values of normalization of Fuzzy AHP and AHP method

Maturity Determinants	Fuzzy AHP Normalized Values	AHP Normalized Values
Customer	(0.5, 0.38, 0.13, 1.0, 0.33)	(0.211 0.193 0.116 0.250 0.230)
Organization	(0.33, 0.83, 0.33, 0.14, 0.33, 0.5, 0.33)	(0.102 0.184 0.106 0.133 0.164 0.188 0.123)
Policy	(0.25, 0.6, 0.14, 0.14, 0.5, 0.12, 0.12)	(0.108, 0.159, 0.105, 0.131, 0.182, 0.149, 0.166)
Process	(0.44, 0.2, 0.29, 0.25, 0.67, 0.5, 0.12)	0.156, 0.141, 0.118, 0.139, 0.162, 0.162, 0.122
Staff	(0.2, 0.33, 0.17, 0.25, 0.2, 0.33, 0.2, 0.29, 0.57)	(0.1, 0.128, 0.101, 0.102, 0.118, 0.113, 0.118, 0.101, 0.119)
Tools	(0.25, 0.33, 0.12, 0.2, 0.14, 0.12, 0.22, 0.33, 0.33, 0.17, 0.2, 0.2, 0.2, 0.17)	(0.088, 0.083, 0.067, 0.06, 0.074, 0.077, 0.061, 0.061, 0.075, 0.056, 0.086, 0.062, 0.082, 0.069)
Value	(0.400, 0.667, 0.600, 0.714, 0.714, 0.750)	(0.109 0.148 0.183 0.225 0.180 0.155)
Vendor	(0.33, 0.67, 0.44, 0.33, 0.12, 0.33)	(0.127, 0.158, 0.187, 0.185, 0.177, 0.166)

Table no. 32: Summery of Fuzzy AHP and AHP results obtained for each procurement maturity identifier

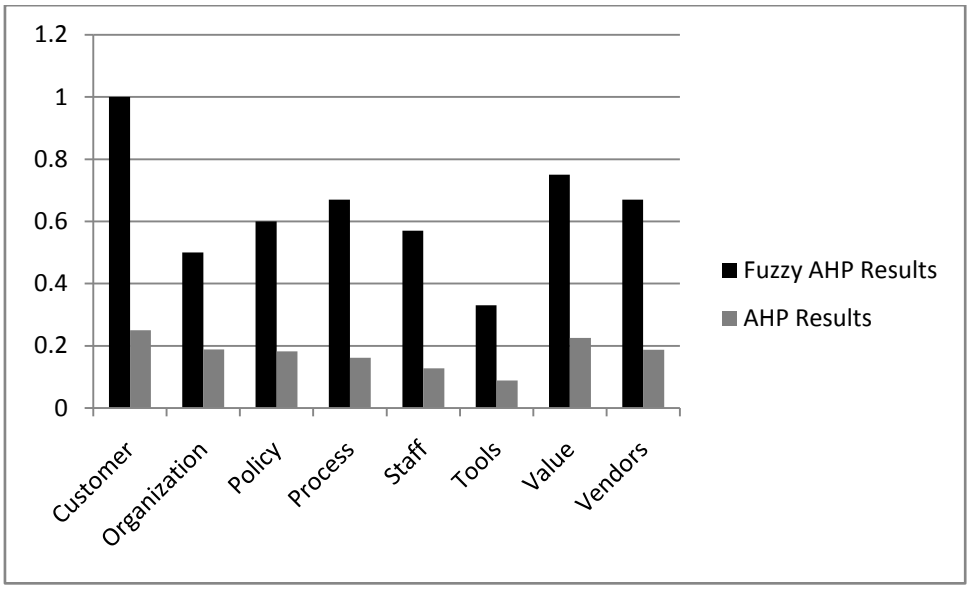
Parameters	Fuzzy AHP Results	AHP Results
Customer	1.0	0.25
Organization	0.5	0.188
Policy	0.6	0.182
Process	0.67	0.162
Staff	0.57	0.128
Tools	0.33	0.088
Value	0.75	0.225
Vendors	0.67	0.187
Total =	5.09 (Grade: C)	1.41 (Grade: E)

VI. Conclusion

Whatever the method goes for implement in practice either Fuzzy AHP or AHP, Stephen Guth's gap analysis has lost its requirement as it has been shown that using fuzzy ratings and normalization processes, maturity level in a sample procurement case has been determined in the illustration without any best case benchmark.

Implementation of such evaluation system in real cases will make a procurement department of a procuring agency not only as an internal strategic player but also an open environmental integrating mechanism which can achieve a high level of clarity in decision making where suppliers, service providers or bidders are treated as resources for the organization. So this system will cross the levels of Purchase Co-ordination, Internal Integration and External Integration levels of Wilco Van's maturity framework [2].

Implementation of determining procurement maturity system will broaden the opportunities where the professionals not only belonged to the procuring agency but also from the funding agency, other procurement agencies, and development partners and from tendering community can put their choice preferences of weight values for different procurement criteria and ratings for different offers from various bidders.



VII. Recommendation

Procurement maturity quantification is achieved using mathematical methods in the illustration where the level of procurement maturity is measured very clearly. Though significant difference is shown in above figure for Fuzzy AHP and AHP method's results, an expert consultant may decide to go with Fuzzy AHP method because of the nature of Fuzzy logic and suitability of Fuzzy computations if not make any confusion to take higher values in maturity concerned area whereas another method determines lower result. We feel that a method research is needed to develop a revised mathematical model that can reduce this discrepancy and produce a same result for methods used.

It is likely to be recommended to develop a web based application where assessors can put their assessment ratings using the linguistics mentioned in this paper and program code according to the mathematical formulas can produce result and display the level of quality achieved automatically. Implementation is truly suggested because it will help to promote a procurement expertise society and procurement professionals will get opportunity to improve the procurement practices worldwide and can effectively participate in development process of underdeveloped societies.

References

[1]. S. R. Guth, Implementing Best Practices: The Procurement Maturity Model National Rural Electric Cooperative Association, 95th ISM Annual International Supply Management Conference, (April 2010)
[2]. W. V. Duinkerken, R. Batenburg, J. Versendaal, The Added Value of E-Procurement for Buyer-Supplier Interaction, IGI International Journal of e-Collaboration (IJeC) Vol. 4, No 1-4 (2008)
[3]. H. A. Taha, Operation Research: An Introduction, Prentice Hall of India Private Limited, Eighth Edition (2008)
[4]. G. J. Klir, B. Yuan, Fuzzy Sets and Fuzzy Logic: Theory and Application, Prentice Hall India Private Limited (2003)
[5]. S. Rajasekaran, G. A. V. Pai, Neural Networks, Fuzzy Logic and Genetic Algorithm: Synthesis and Application, Prentice Hall of India Private Limited (2007)

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