Fuzzy Analytical Hierarchy Process in Selection of a Seventh Party Logistics (7PL)

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ABSTRACT:

This paper projects the implementation and application of Fuzzy Analytical Hierarchy Process and the six steps of implementation are discussed. Fuzzy AHP and its necessity and related concepts like alpha cut are structured in this paper. In the Fuzzy Extent Analysis method and α-cut based method, FAHP is described to obtain a crisp priority vector from a triangular fuzzy comparison matrix. Analytical Hierarchy Process (AHP) which especially is based on pair-wise comparisons on a ratio scale. In this present research, initially, the criteria for selection of logistics service providers (7PL) have been identified and an integrated model based on their inter-relationship has been developed with the help of consigner.

Keywords: *Fuzzy Analytical Hierarchy Process (FAHP), Analytical Hierarchy Process (AHP), 7PL service provider*

I. INTRODUCTION

This method is often criticized for its inability to adequately handle the inherent uncertainty and imprecision associated with the mapping of decision-makers perception to exact numbers [1]. Since fuzziness and vagueness are common characteristics in many decision- making problems, a Fuzzy Analytical Hierarchy Process (FAHP) method should be able to tolerate vagueness or ambiguity. In other words, the conventional AHP approach may not fully reflect a style of human thinking because the decision makers usually feel more confident to give interval judgments rather than expressing their judgments in the form of single numeric values and so FAHP is capable of capturing a human's appraisal of ambiguity when complex multi-attribute decision making problems are considered [2]. The essence of the process is decomposition of a complex problem into a hierarchy with goal (criterion) at the top of the hierarchy, criteria and sub-criteria at levels and Sub-levels of the hierarchy and decision alternatives at the bottom of the hierarchy[5]. Based on the literature survey [6, 7, 8] and discussion with the decision makers (team of experts from academia and industry), a list of criteria have been identified and an appropriate hierarchy of the AHP model consisting of the goal, criteria, sub-criteria and the alternatives, is formulated.This ability comes to exist when the crisp judgments transformed into fuzzy judgments.

II. FUZZY ANATYTICAL NETWORK PROCESS

Fuzzy Extent Analysis Different methods have been proposed in the literatures. One of the most known of them is Fuzzy Extent Analysis proposed by Chang [3]. Fuzzy sets—described the mathematics of fuzzy set theory—was a generalization of classic set theory, allowed the membership functions to operate over the range of real numbers (0, 1). The main characteristic of fuzziness is the grouping of individuals into classes that do not have sharply-defined boundaries [4]. The uncertain comparison judgment can be represented by the fuzzy number. A triangular fuzzy number is the special class of fuzzy number whose membership is defined by three real numbers, expressed as (l, m, u).

The triangular fuzzy numbers is represented as follows: In order to understand and apply fuzzy set theory further, some important definitions are reviewed firstly:

1. A fuzzy set Ậ in a universe of discourse U is characterized by a membership function $u_A(x)$ that takes values in the interval (0, 1). $u_A(x)$ is assigned to express the membership of x to Ậ.

2. The height of a fuzzy set is the largest membership value attained by any point. If the height of a fuzzy set is equal to one, i.e., $u_A(x) =1$, it is called a normal fuzzy set.

3. An α-cut of a fuzzy set Ậ is a crisp set Ậα that contains all the elements in U that have memberships values in Ậ greater than to α, that is Ậα = {x€ U $u_A(x) \geq \alpha$}

Triangular Fuzzy Number A fuzzy number Ã must possess following properties: 1. $u_{\tilde{A}}(x) = 0$ for all x ϵ (-∞ ,L]; 2. $u_{\tilde{A}}(x)$ is strictly increasing on (L, M); 3. $u_{\tilde{A}}(x) =1$ for x= M;

4. uÃ(x) is strictly decreasing on (M ,U);

5. $u_{\tilde{A}}(x) =0$ for all x ϵ (U , ∞);

Let Ã be a triangular fuzzy number with a triplet (L, M, U). The membership can be defined as,

$u_{\tilde{A}}(x)$ = (x –L)/ (M-L); $L \leq x \leq M$

= (U – x)/(U-M); $M \leq x \leq U$

= 0. Otherwise

The fuzzy inference process integrates the rules in fuzzy rule base and then implements a mapping from fuzzy set Ậ in the universe of discourse U to fuzzy set Ñ the universe of discourse V .Due to the input and output of a fuzzy system are real-valued numbers in most applications, one must construct interfaces, fuzzifier and defuzzifier, between the fuzzy inference process and the environment. The fuzzification process represents a process of mapping a real- valued x €U R^n to a fuzzy Ậ in U.

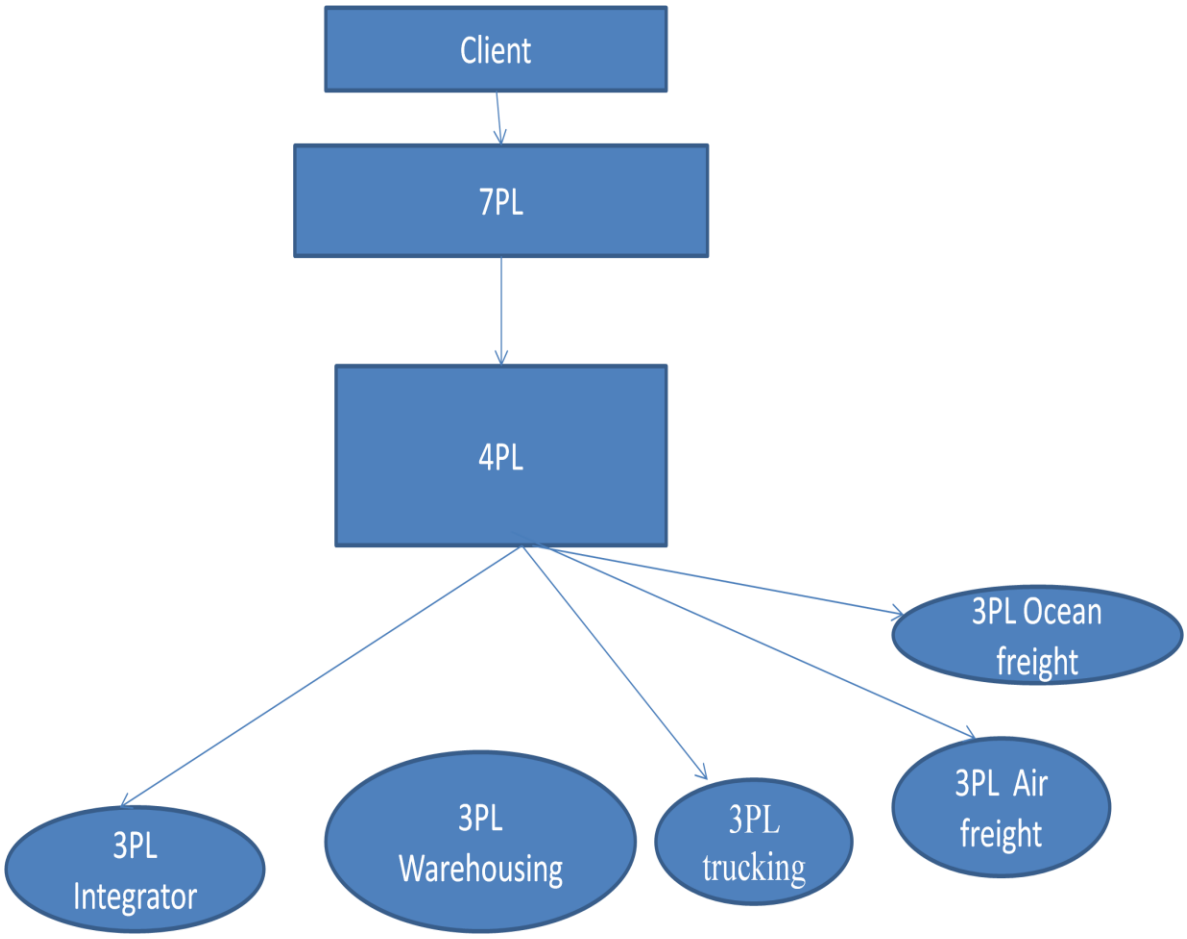

Fig 2.1 Structure of Seventh Party Logistics.

A. DEFUZZIFICATION METHOD

Various defuzzification methods are available in the literature, and the method adopted in this study was derived from Hus and Nian as well as Lious and Wang. As shown in the formula below, this method can clearly express fuzzy perception. Owing to the ability of this method to explicitly display the preference (α) and risk tolerance (λ) of the decision makers, they can more thoroughly understand the risks they face under different circumstances. Notably, α can be viewed as a stable or fluctuating condition (Hsu and Yang, 2000). The range of uncertainty is greatest when α=0. Meanwhile, the decision-making environment stabilizes when increasing a while, simultaneously, the variance for decision decreases.

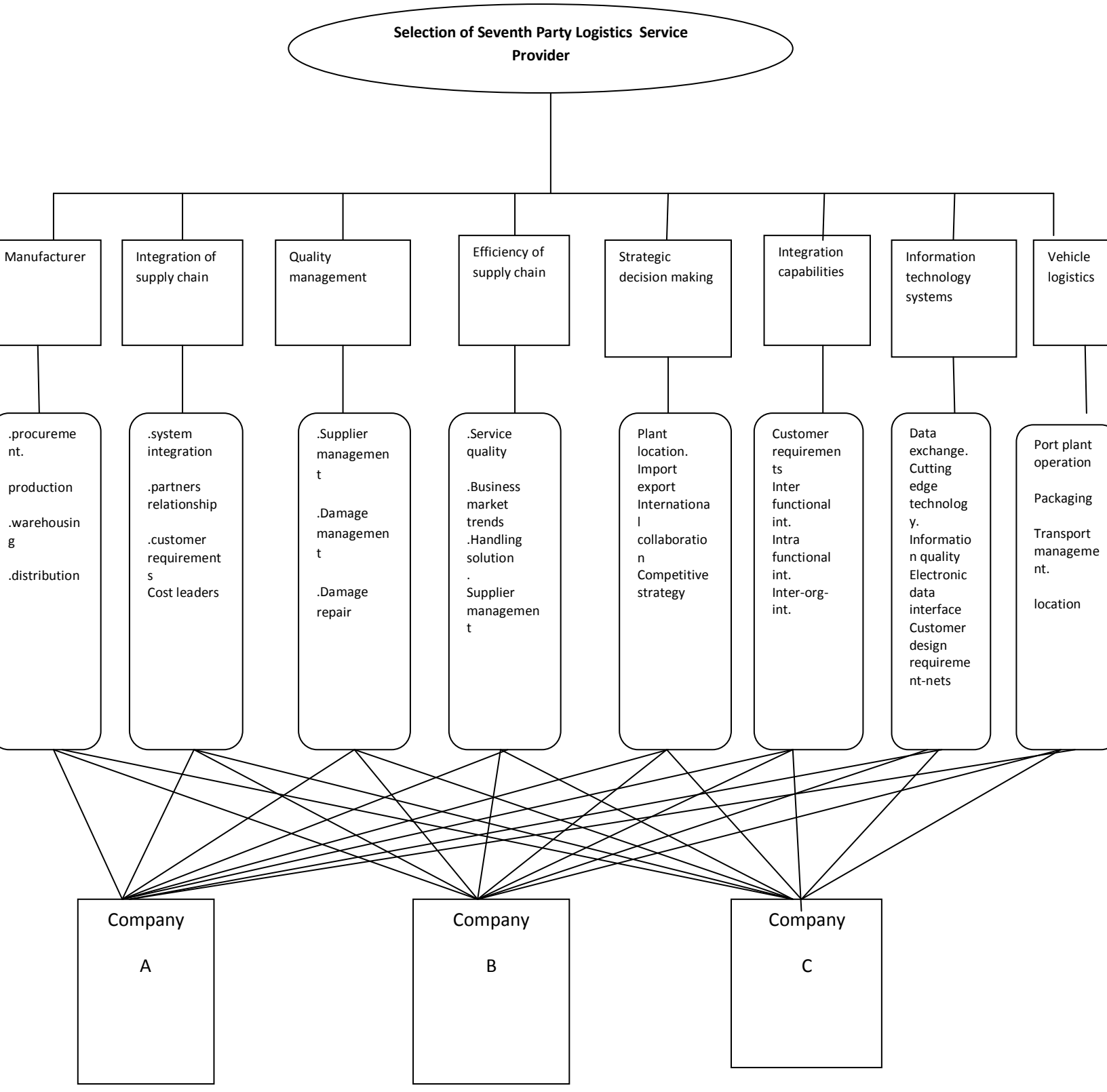

Fig 2 Seventh Party Logistics Model

Additionally, α can be any number between 0 and 1. Besides while α =0 represents the upper bound U_1 and lower-bound L_1 of triangular fuzzy numbers and while, α=1 represents the geometric mean M_1 in triangular fuzzy numbers, λ can be viewed

as the degree of a decision maker's pessimism. When λ is 0, the decision maker is more optimistic and thus, the expert consensus is upper bound Uij of the triangular fuzzy number. Conversely, when λ = 1, the decision maker is pessimistic, and the umber ranges from 0 to 1. However in this study, value of α is taken as 0.5.

Furthermore, the evaluator can be based on their own judgment, and adopt a conservative or optimistic attitude when determining λ value. Where λ =0 represents the most pessimistic scenario. In this study it is decided to take the middle–road and assigned λ = 0.5.

$(aij\alpha) = [\lambda . \ Lij\alpha + (1-\lambda) \ . \ Uij\alpha]$,

$0 \leq \lambda \leq 1, 0 \leq \alpha \leq 1$, where,

$Lij\alpha = (Mij - Lij). \alpha + Lij$ $Uij\alpha = Uij - (Uij - Mij).\alpha$ $Lij\alpha$ represents the left end value of α-cup for aij and Uij represents the right end value of α-cup for aij.

a) PRIORITY CALCULATIONS BY FAHP

Evaluating various 7PL service providers includes following steps:

Step 1: Define evaluative criteria and sub-criteria for selection of best 7PL service provider.

Step 2: Establish a hierarchical structure. Step 1 and Step 2 are already performed in AHP.

Step 3: Establish the triangular fuzzy numbers based on experts group interviews, decision- makers opinion and questionnaire which was attached along with the questionnaire of AHP. Based on the questionnaire results by decision maker's the fuzzy Pair-wise Comparison Judgemental Matrices (PCJMs).

Step 4: Perform defuzzification using the formula. Performing similar operation on each PJCM, we get fuzzy aggregate pair-wise comparison matrix for each level.

Step 5: Calculate relative weights of the elements in each level. Each of these matrices is then translated into the corresponding largest eign value problem and is solved to find the normalized and priority weights of each criterion. With the sum-approach, the normalized priority weights are determined. Consistency Ratio (CR) of each PCJM is calculated, which is compared with the rule-of-the-thumb value of CR (RCR). Rule of thumb value of CR is 10% or 0.1. If the calculated CR is well below the corresponding RCR, it clearly implies that the decision maker is consistent in assigning pair wise comparison judge-ments. Otherwise, the PCJMs are invalid and should be reassigned by the decision maker. If all the PCJMs passes the consistent inspection, we should use the normalized priority weights to calculate the evaluation of each integrated service provider.

Step 6: The weights obtained for each alternative (A, B and C) are same as that of performance evaluation by AHP.

Step 7: Combination of relative weights of the elements of each level to determine the synthesis value of each alternative. Thus, the values are obtained. From the final values, we can conclude that service provider.

Consider the criteria's values as weighted using pair wise comparison in matrices, we have

Table 2.1 Global Goal Matrix

Goal	Manu	ISC	QMT	ESC	SDM	IC	ITS	VL
Manu	1,1,1	1,2,3	2,5,7	3,5,6	4,5,6	4,5,5	5,6,8	3,5,7
ISC	1,1/2,1/3	1,1,1	2,3,5	3,4,4	5,6,7	4,5,7	5,6,9	4,5,5
QMT	1/2,1/5,1/7	1/2,1/3,1/5	1,1,1	1/3,1/4,1/4	1,1/2,1/4	3,5,6	2,4,5	3,4,5
ESC	1/3,1/5,1/6	1/3,1/4,1/4	3,4,4	1,1,1	½,1/3,1/4	1/3,1/4,1/5	½,1/4,1/5	2,3,5
SDM	1/4,1/5,1/6	1/5,1/6,1/7	1,2,4	2,3,4	1,1,1	5,6,9	6,8,9	3,4,4
IC	1/4,1/5,1/5	¼,1/5,1/7	1/3,1/51/6	3,4,5	1/5,1/6,1/9	1,1,1	2,3,4	4,5,7
ITS	1/5,1/6,1/8	1/5,1/6,1/9	½,1/4,1/5	2,4,5	1/6,1/8,1/9	1/2,1/3,1/5	1,1,1	2,3,4
VL	1/3,1/5,1/7	¼,1/5,1/5	1/3,1/4,1/5	½,1/3,1/4	1/3,1/4,1/4	¼,1/5,1/7	½,1/3,1/4	1,1,1

Table2.2 Goal- 1 Manufacturer- Fuzzy pair wise comparison judgement matrix

Manu	Proc	Prod	WH	DIS
Proc	1,1,1	2,4,5	4,5,6	5,6,8
Prod	½,1/4,1/5	1,1,1	2,3,5	5,6,7
WH	½,1/4,1/5	½,1/3,1/5	1,1,1	3,4,6
DIS	1/5,1/6,1/8	1/5,1/6,1/7	1/3,1/4,1/6	1,1,1

Table2.3 Goal-2Intgeration of supply chain Fuzzy pair wise comparison judgement matrix

ISC	IS	CR	CL	PR
IS	1,1,1	1,2,4	3,5,6	2,5,7
CR	1,1/2,1/3	1,1,1	1/3,1/4,1/6	2,3,5
CL	1/3,1/5,1/6	1/3	1,1,1	4,5,5
PR	½,1/5,1/7	½,1/3,1/5	¼,1/5,1/5	1,1,1

Table2.4 Goal-3 Quality Management - Fuzzy pair wise comparison judgement matrix

QMT	SM	DM	DR
SM	1,1,1	3,5,7	4,5,7
DM	1/3,1/5,1/7	1,1,1	3,5,6
DR	¼,1/5,1/7	1/3,1/5,1/6	1,1,1

Table2.5 Goal-4 Efficiency of Supply Chain - Fuzzy pair wise comparison judgement matrix

ESC	SQ	SM	B/MT
SQ	1,1,1	½,1/3,1/4	2,3,5
SM	2,3,4	1,1,1	2,4,5
B/MT	½,1/3,1/5	½,¼,1/5	1,1,1

Table 2.6 Goal-5 Strategic Decision Making -Fuzzy pair wise comparison judgement matrix

SDM	CS	IC	I/E	PL
CS	1,1,1	2,3,5	3,5,7	5,6,8
IC	½,1/,1/53	1,1,1	2,3,5	3,5,6
I/E	1/3,1/5,1/7	½,1/3,1/5	1,1,1	3,4,5
PL	1/5,1/6,1/8	1/3,1/5,1/6	1/3,1/4,1/5	1,1,1

Table2.7 Goal-6 Integration Capabilities -Fuzzy pair wise comparison judgement matrix

ICS	CR	I.F.I	I.O.I	RL
CR	1,1,1	2,3,5	3,5,6	4,5,6
I.F.I	½,1/3,1/5	1,1,1	5,6,9	6,8,9
I.O.I	1/3,1/5,1/6	1/5,1/6,1/9	1,1,1	3,4,5
RL	¼,1/5,1/6	1/6,1/8,1/9	1/3,1/4,1/5	1,1,1

Table2.8 Goal-7 Information Technology Systems -Fuzzy pair wise comparison judgement matrix

ITS	CDR	IQ	DE	CET	ET
CDR	1,1,1	3,4,4	3,4,5	4,5,6	5,6,9
IQ	1/3,1/4,1/4	1,1,1	2,3,3	3,4,6	3,5,7
DE	1/3,1/4,1/5	,1/21/3,1/3	1,1,1	3	6
CET	¼,1/5,1/6	1/3,¼,1/6	1/3	1,1,1	2
ET	1/5,1/6,1/9	1/3,1/5,1/7	1/6	1/2	1,1,1

Table2.9 Goal-8 Vehicle Logistics -Fuzzy pair wise comparison judgement matrix

VL	PPL	PK	TM	L
PPL	1,1,1	1,2,3	1,2,4	2,3,4
PK	1,1/2,1/3	1,1,1	½,1/3,1/4	1,½,1/4
TM	1,1/2,1/4	2,3,4	1,1,1	3,4,4
L	½,1/3,1/4	1,2,4	1/3,1/4,1/4	1,1,1

III. RESULTS AND DISCUSSION

In order to satisfy all the customer requirements, the concept of Seventh party logistics (7PL) service provider, providing the integrated services has been emerged. It has been the sole point of contact between company and its array of logistics and information service provider. In this study proposes an analytical approach for the selection of integrated or 7PL service providers in crisp and fuzzy environments.

After De-fuzzification, We have tabular values as follows:

Table3.1 Global Goal Matrix C.I = 0.18649

Goal	Manu	ISC	QMT	ESC	SDM	IC	ITS	VL	Priority
Manu	1	2.25	4.75	5.25	5.5	4.75	6.25	5	0.32896
ISC	½.25	1	3.25	3.75	6	5.25	6.25	4.75	0.25625
QMT	¼.75	1/3.25	1	1/3	1/2	5.25	3.75	4	0.10628
ESC	1/5.25	1/3.75	3	1	1/3	1/3	1/4	3.25	0.065117
SDM	1/5.5	1/6	2	3	1	6.25	7.75	3.75	0.12246
IC	¼.75	1/5.25	1/5.25	3	1/6.25	1	3.25	5.25	0.57936
ITS	1/6.25	1/6.25	1/3.75	4	1/7.25	1/3.25	1	3	0.036235
VL	1/5	1/4.75	1/4	1/3.25	1/3.75	1/5.25	1/3	1	0.026743

Table 3:2Goal-1 Manufacturer- De-fuzzied pair wise comparison judgement matrix
C.I = 0.1029

Manu	Proc	Prod	WH	DIS	Priority
Proc	1	3.75	5.5	6.25	0.57782
Prod	1/3.75	1	3.25	6.5	0.25674
WH	1/5.5	1/3.25	1	4.25	0.11755
DIS	1/6.25	1/6.5	¼.25	1	0.04822

Table3:3 Goal-2 Integration of supply chain - De-fuzzied pair wise comparison judgement matrix.
C.I = 0.08264

ISC	IS	CR	CL	PR	Priority
IS	1	2.25	5.25	4.75	0.54344
CR	½.25	1	1/4	3.25	0.19954
CL	1/5.25	4	1	4.75	0.19053
PR	¼.75	1/3.25	¼.25	1	0.06647

Table3:4 Goal-3 Quality Management - De-fuzzied pair wise comparison judgement matrix
C.I = 0.14739

QMT	SM	DM	DR	Priority
SM	1	5	5.25	0.68804
DM	1/5	1	5.25	0.23553
DR	1/5.25	1/5.25	1	0.07664

Table3:5 Goal-4 - Efficiency of Supply Chain De-fuzzied pair wise comparison judgement matrix
C.I = 0.00113

ESC	SQ	SM	B/MT	Priority
SQ	1	1/3	3.25	0.42694
SM	3	1	3.75	0.44780
BMT	1/3.25	1/3.75	1	0.12524

Table3.6 Goal-5 Strategic Decision Making - De-fuzzied pair wise comparison judgement matrix.
C.I = 0.09252

SDM	CS	IC	I/E	PL	Priority
CS	1	3.25	5	5.5	0.55105
IC	1/3.25	1	3.25	5.25	0.26657
I/E	1/5	1/3.25	1	4	0.12665
PL	1/5.5	1/5.25	¼	1	0.05572

Table3.7 Goal-6 Integration Capabilities - De-fuzzied pair wise comparison judgement matrix.
C.I = 0.18284

ICS	CR	I.F.I	I.O.I	RL	Priority
CR	1	3.25	5.25	5.5	0.54430
I.F.I	1/3.25	1	6.5	7.75	0.31493
I.O.I	1/5.25	1/6.5	1	4	0.09474
RL	1/5.5	1/7.75	¼	1	0.046015

Table 3.8 Goal-7 Information Technology Systems - De-fuzzied pair wise comparison judgement matrix.

C.I = 0.06308

ITS	CDR	IQ	DE	CET	ET	Priority
CDR	1	3.75	4	5.5	6.5	0.49662
IQ	1/3.75	1	2.75	4.25	5	0.25922
DE	¼	½.75	1	1/3	1/4	0.08807
CET	1/5.5	¼	3	1	3	0.09757
ET	1/6.5	1/5	4	1/3	1	0.05851

Table 3.9 Goal-8 Vehicle Logistics- De-fuzzied pair wise comparison judgement matrix
C.I = 0.06415

VL	PPL	PK	TM	L	Priority
PPL	1	2	2.25	3	0.42201
PK	½	1	1/3	½	0.18819
TM	½.25	3	1	3.75	0.26467
L	1/3	2	1/3.75	1	0.25068

Each goal matrices, now considered with the alternatives and over all weights are calculated for final selection:

Criteria	Company A	Company B	Company C
MAN	0.3235	0.3193	0.3202
ISC	0.3681	0.3217	0.3109
QMT	0.3665	0.2878	0.3552
ESC	0.3908	0.3213	0.3124
SDM	0.3663	0.3136	0.3140
IC	0.3715	0.2889	0.3389
ITS	0.3540	0.3074	0.3381
VL	0.3472	0.3211	0.3292

The final values, after finding overall weighted values we have

Company A	Company B	Company C
0.3534	0.3114	0.3221

IV. CONCULSION

The present work helps the consigner and the decision makers in evaluating the 7PL service providers based on the selection criteria. Both the crisp and fuzzy environments enable the decision makers to arrive at an accurate decision. The proposed methodology helps the decision makers to include both the qualitative and quantitative criteria in the evaluation process. Pair wise comparison using triangular fuzzy numbers help in reducing the vagueness and impreciseness which otherwise largely persist in any human judge mental decision. A systematic approach using FAHP has been applied for 7PL service provider selection. The results show that the model has the capability to be flexible and be applied in different types of industries to choose the 7PL service provider.

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