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VENDOR SELECTION IN SUPPLYCHAIN MANAGEMENT USING ISM AND ANP

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ABSTRACT: *A vendor, or a supplier, in a supply chain management is anyone who provides goods or services to a company. Thus, the raw materials required for the manufacture of a product will be provided by the supplier. These raw materials are processed to obtain the finished product by the manufacturer. The finished product will be sold to the customers. A supply chain is a system of organizations, people, technology, activities, information and resources involved in moving a product or service from supplier to customer. Supply chain activities transform natural resources, raw materials and components into a finished product that is delivered to the end customer. The aims of this paper to identify the various risk factors in supply chain management, then to evaluate it using Interpretive Structural modelling and then the relationship between the factors is evaluated using Analytical Network process. Then the selection of best supplier is done using Analytical Network process.*

Keywords: *Analytical Network Process, Interpretive Structural Modelling, Pairwise comparison matrix, Supplier selection, Supply Chain Management.*

I. INTRODUCTION

1.1 Supply Chain Network:

A supply chain is a system of organizations, people, technology, activities, information and resources involved in moving a product or service from supplier to customer. Supply chain activities transform natural resources, raw materials and components into a finished product that is delivered to the end customer. Supply Chain Management (SCM) was developed to express the need to integrate the key business processes, from end user through original suppliers. A vendor, or a supplier, in a supply chain management is anyone who provides goods or services to a company. Thus, the raw materials required for the manufacture of a product will be provided by the supplier. These raw materials are processed to obtain the finished product by the manufacturer. The finished product will be sold to the customers. (6)

In today's competitive business, buying firms increasing rely on their suppliers to deliver technologically advanced, defect-free products in a timely and cost-effective manner. If the supplier lacks in some of these areas, buying firms face the decision of whether to look for an alternative source of supply or to work with the same supplier and to remedy their shortcomings. Because of the uncertainty of locating a better source, and the high cost of searching and evaluating new suppliers, buying firms may engage in supplier development. (3) Manufacturing firms on the average spend over 50% of its revenues on purchasing inputs.

Vendor selection and evaluation is one of the most critical activities. Selection of a wrong vendor or source could be enough to upset the company's financial and operational position. Traditionally vendors are selected on their ability to meet the quality requirements, delivery schedule and the price offered. However, in modern management, one needs to consider many other factors with the aim of developing a long-term vendor relationship. (8) Vendors are considered as the best intangible assets of any organization. Basically, the selection process involves evaluation of different alternative vendors based on various criteria.

1.2. Supplier selection:

Supplier selection is the process by which firms identify, evaluate, and contract with suppliers. The supplier selection process deploys a tremendous amount of a firm's financial resources. In return, firms expect significant benefits from contracting with suppliers offering high value. Evaluation and selection of Suppliers is a typical multiple criteria decision making (MCDM) problem involving multiple criteria that can be both qualitative and quantitative. The selection process involves the identification of potential criteria and performance assessment of suppliers with reference to selected criteria thus necessitating a systematic approach or methodology.(12)

1.3. Importance of Supplier selection

1. Suppliers play an important role to ensure quality products and safety standards for an organization.
2. The organization should give priority to the selection of suppliers.
3. The selection of inefficient suppliers affects the organization directly and also the customers indirectly.
4. The selection of supplier plays a solid role in the competitive business environment.

1.4. Interpretive Structural Modelling (ISM)

Interpretive structural modelling (ISM) is a well-established methodology for identifying and summarizing relationships among specific items which define an issue or problem. Interpretive structural modelling (ISM) is an interactive learning process. The result of ISM is a directed graph or digraph, which is called the ISM model. This model helps to identify the hierarchy of factors that influencing supplier selection. The Interpretive Structural Modelling (ISM) approach has employed to develop the structural relationship among supplier development factors and also tried to define the levels of different factors based on their driver/dependence power and their mutual relationships.(8)

1.5. Steps for ISM

The typical steps for developing the ISM model are,

1. Identification of factors
2. Determine the contextual relationship
3. Structural Self Interaction Matrix(SSIM)
4. Initial Reachability Matrix
5. Transitivity check
6. Final Reachability Matrix
7. Driver power- Dependence Matrix
8. Level partitioning
9. Lower triangular Matrix
10. Formation of Digraph

1.6. Analytic Network Process (ANP)

ANP is a comprehensive decision-making technique that has the capability to include all the relevant criteria, which have some bearing, in arriving at a decision. Analytic network process (ANP) captures interdependencies among the decision attributes and allows a more systematic analysis. It also allows inclusion of all the relevant criteria that have some bearing in arriving at the best decision. ANP provides a more generalized model in decision-making without making assumptions about the independency of the higher-level elements from lower-level elements and also of the elements within a level. (14)

1.7. ANP Methodology

The following steps are followed in ANP,

1) Model development
2) Pair wise comparison of dimensions
3) Pair wise comparison of enablers
4) Pair wise comparison of enablers for interdependencies
5) Evaluation of suppliers
6) Super matrix formation
7) Selection of the best supplier

II. DEVELOPMENT OF THE INTEGRATED MODEL

2.1. INTERPRETIVE STRUCTURAL MODELLING:

2.1.1 Identification of factors:

1. Quality
2. Price
3. Delivery
4. Production facilities

5. Technology and Innovation
6. Surge capacity
7. Planning
8. Service
9. Transport and communication
10. Top level commitment
11. Reputation
12. Financial stability
13. Attitude and Willingness
14. Compatibility
15. Risk Management
16. Inspection of goods
17. Infrastructure
18. Packaging ability
19. Geographical spread range
20. Agility

2.1.2. Structural Self Interaction Matrix(SSIM)
Table2.1 Structural Self Interaction Matrix (SSIM)

A: Factor for j leads to factor i
V: Factor for i leads to factor j
X: Factor for i leads factor j and factor j leads to factor i
O: No relationship between i and j

2.1.3. Initial Reachability Matrix
1. If the (i, j) entry in the SSIM is V, then the (i, j) entry in the reachability matrix becomes 1 and the (j, i) entry becomes 0.
2. If the (i, j) entry in the SSIM is A, then the (i, j) entry in the reachability matrix becomes 0 and the (j, i) entry becomes 1.
3. If the (i, j) entry in the SSIM is X, then the (i, j) entry in the reachability matrix becomes 1 and the (j, i) entry also becomes 1.

	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
1	O	O	A	A	A	O	V	O	O	V	A	O	O	A	O	A	A	O	V	
2	O	O	A	O	O	O	O	A	O	O	O	A	O	O	A	O	A	O		
3	A	A	O	A	O	O	O	A	O	V	A	A	O	A	O	O	A			
4	A	O	O	A	O	O	O	V	O	V	O	O	O	O	V	O				
5	V	O	O	O	V	X	O	V	O	V	O	O	V	V	V					
6	A	O	O	O	O	A	X	V	A	V	O	O	O	O						
7	O	O	O	O	V	O	O	V	A	O	A	O	O							
8	O	A	O	O	O	O	X	A	A	V	A	A								
9	O	X	O	O	O	O	V	V	O	V	O									
10	O	O	O	V	V	V	V	V	O	O										
11	V	X	O	V	O	V	V	V	V											
12	V	V	O	V	O	O	O	V												
13	V	O	O	O	O	V	X													
14	O	O	O	O	O	O														
15	A	O	O	O	O															
16	O	O	O	O																
17	O	O	O																	
18	O	O																		
19	O																			
20																				

4. If the (i, j) entry in the SSIM is 0, then the (i, j) entry in the reachability matrix becomes 0 and the (j, i) entry also becomes 0.
Thus, a binary matrix called the initial reachability matrix can be obtained.

2.1.4 Transitivity check

Transitivity checks have to be carried out to extract a consistent model from the set of factors. Transitivity of the contextual relation is a basic assumption in ISM which states that if element A is related to B and B is related to C, then A is related to C i.e. If element 'i' is related to 'k' and 'k' is related to 'j', then 'i' is related to 'j'.

2.1.5. Final Reachability Matrix

Table2.2. Final Reachability Matrix

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	D.P	Rank
1	1	1	0	0	0	1	0	1	0	0	1	0	1	1	0	0	0	0	0	0	7	11
2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	20
3	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	2	19
4	1	1	1	1	0	1	0	1	0	0	1	0	1	1	0	0	0	0	0	0	9	6.5
5	1	1	1	1	1	1	1	1	0	0	1	0	1	1	1	1	0	0	0	1	14	2.5
6	0	1	1	0	0	1	0	1	0	0	1	0	1	1	0	0	0	0	0	0	7	11
7	1	1	1	0	0	0	1	1	0	0	1	0	1	1	0	0	0	0	0	0	8	8.5
8	0	0	0	0	0	0	0	1	0	0	1	0	0	1	0	0	0	0	0	0	3	17.5
9	0	1	1	0	0	1	0	1	1	0	1	1	1	1	0	0	0	0	1	0	10	4.5
10	1	1	1	1	1	1	1	1	0	1	1	0	1	1	1	1	1	0	0	0	15	1
11	0	1	0	0	0	0	0	0	0	0	1	1	1	1	1	0	1	0	1	1	9	6.5
12	0	1	1	1	0	1	1	1	0	0	0	1	1	1	1	1	1	0	1	1	14	2.5
13	0	1	1	0	0	0	0	1	0	0	0	0	1	1	1	0	0	0	0	1	7	11
14	0	0	0	0	0	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	3	17.5
15	0	0	0	0	1	1	1	0	1	0	0	0	0	0	1	1	0	0	0	0	6	13.5
16	1	0	0	0	0	0	0	0	0	0	1	0	0	1	0	1	0	0	0	0	4	16
17	1	1	1	1	0	1	0	0	0	0	0	0	1	1	0	0	1	0	0	0	8	8.5
18	1	1	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	1	0	0	5	15
19	0	0	1	0	0	0	0	1	1	0	1	0	1	1	1	0	1	0	1	1	10	4.5
20	0	0	1	1	0	1	0	0	0	0	0	0	0	1	1	0	0	0	0	1	6	13.5
	8	13	12	6	3	11	5	11	3	1	13	3	13	17	8	5	5	1	4	6		

After transitivity embedding, the modified final Reachability matrix can be obtained. From final Reachability Matrix the Driver power- Dependence are calculated for each factor. The summation of row indicates the Driver power and the summation of column indicates the Dependence.

2.1.5 Driver power- Dependence Matrix

Driver Power

20																				
19																				
18																				
17																				
16			IV																	
15	10													III						
14			5,12																	
13																				
12																				
11																				
10			9	19																
9						4							11							
8					7,17															
7								1			6		13							
6						20		15												
5			I	18										II						
4					16															
3											8									
2																	14			
1												3	2							
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20

Fig 4.1 Driver power- Dependence Matrix

1) Autonomous factors- I quadrant
2) Dependent factors- II quadrant
3) Linked factors- III quadrant
4) Driver /Independent factors- IV quadrant

The dependent factors derived from this matrix will be then worked in ANP.
From the driver power dependence matrix we found that,

Autonomous Factors -4, 7, 9, 16, 17, 18, 19, 20
Dependence factors - 1,2,3,6,8,11,13,14,15
Linked -Nil
Driver -5, 10, 12

From the driver power dependence matrix, the dependence factors are

1) Quality (QY)
2) Price (PR)
3) Delivery (DY)
4) Surge capacity (SC)
5) Service (SER)
6) Reputation (RPT)
7) Attitude and Willingness (AW)
8) Relationship and Trust (RT)
9) Risk Management (RM)

Thus, from the Driver power Dependence Matrix, we selected the **Dependence factors** and we worked on those factors on ANP to produce an integrated model for the Vendor selection.

2.2 Analytic Network Process (ANP)

2.2.1. Model development

The input factors for ANP are classified into two categories. These categories have been named as

i. Dimensions
ii. Enablers

The dimensions are Performance (PR), Customer satisfaction (CS), Long Term Relationship (LTR). The various factors are considered as the Enablers. The Quality, Price, Reputation depends on Performance. Delivery, Surge Capacity, Risk Management depends on Customer Satisfaction. Service, Attitude and willingness, Relationship and Trust depends on Long Term Relationship.

2.2.2. Pair wise comparison of dimensions

In this step, the relative importance of each dimension for a determinant is obtained through a pair wise comparison matrix. The Pair wise comparisons of dimensions are shown in the following tables.

Table 2.3. Pair wise comparison of dimensions

	PM	CS	LTR	e
PM	1	2	3	0.539
CS	1/2	1	2	0.297
LTR	1/3	1/2	1	0.164
	1.833	3.5	6	1

Checking:

□max= 1/n(W1/w1+W2/w2+…..Wn/wn)

Where, n= No. of parameters, w=element from e-vector, W=elements from the matrix multiplication of pair wise comparison matrix and e-vector

C.I= $\frac{\lambda max-n}{(n-1)}$ C.R.= $\frac{C.I.}{R.I.}$

Where R I is taken from the below table

Table 2.4. R I table

n	1	2	3	4	5	6	7	8	9	10
R.I.	0	0	0.58	0.9	1.12	1.24	1.34	1.41	1.45	1.49

The procedure followed for the pair wise comparison matrix will be correct if and only if the critical ratio C R is less than or equal to 0.1

i. e. **CR<0.1**

2.2.3. Pair wise comparison of enablers

In this step, the pair wise comparison of elements at each level is conducted with respect to their relative influence towards their control criterion.

Table 2.5 Pair wise comparison of enablers under Performance

	QY	PR	RPT	e
QY	1	2	4	0.571
PR	½	1	3	0.286
RPT	1/4	1/3	1	0.193
	1.533	4.25	10	1.000

Likewise the pairwise comparison of other enablers under the various factors was taken.

2.2.4. Evaluation of suppliers

The final set of pair wise comparisons is made for the relative impact of each of the outsourcing alternatives (A, B, and C) on the enablers in influencing the dimensions. The number of such pair wise comparison matrices is dependent on the number of enablers that are included in each dimension.
Evaluation for Suppliers based on Quality, Price, Reputation and so on.

Table 2.6. Evaluation based on Quality

	A	B	C	e
A	1	3	1/2	0.320
B	1/3	1	1/4	0.123
C	2	4	1	0.557
	3.333	8	1.75	1.000

The evaluation of the suppliers based on the other factors was also evaluated.

2.2.5. Formation of Super matrix

The super-matrix allows for a resolution of interdependencies that exist among the elements of a system. It is a partitioned matrix where each sub-matrix is composed of a set of relationships between and within the levels as rep- resented by the decision-makers model. The super-matrix *M* presents the results of the relative importance measures for each of the enablers.

The elements of the super-matrix have been imported from the pair wise comparison matrices of interdependencies. Each of the non-zero values in a column is the relative importance weight associated with the interdependent pair wise comparison matrices.

Table 4.26 Super Matrix before Convergence

	QY	PR	DY	SC	SER	RPT	AW	RT	RM
QY	0	0.75	0.333						
PR	0.667	0	0.667						
DY	0.333	0.23	0						
SC				0	0.25	0.333			
SER				0.333	0	0.667			
RPT				0.667	0.75	0			
AW							0	7.5	0.25
RT							0.667	0	7.5
RM							0.333	0.25	0

For convergence to occur, the super-matrix needs to be column stochastic. In
other words, the sum of each column of the super- matrix needs to be one. Raising the super-matrix to the power 2^{k+1}, where k is an arbitrarily large number, allows convergence.
Super matrix after Convergence:
The below matrix is obtained by the repeated multiplication of the resultant matrix with the parent matrix (matrix before convergence). Regarding our project we had multiplied nearly 30 times to obtain the converged super matrix.

Table 4.27 Super matrix after Convergence

	QY	PR	DY	SC	SER	RPT	AW	RT	RM
QY	0.377	0.377	0.377						
PR	0.402	0.402	0.402						
DY	0.226	0.226	0.226						
SC				0.227	0.227	0.227			
SER				.355	.355	.355			
RPT				.418	.418	.418			
AW							.365	.365	.365
RT							.412	.412	.412
RM							.225	.225	.225

2.2.6. Selection of the best supplier

The selection of the best provider depends on the values of various desirability indices. These desirability indices indicate the relative importance of the alternatives in supporting dimensions.

Table 4.28 Selection of the Best Supplier

Dimensions	Attributes	Tab 1	Tab 2	Tab 3	Tab 4 (A)	Tab 5 (B)	Tab 6 (C)	A	B	C
PM	QY	.539	.571	.377	.320	.123	.557	.03713	.01427	.06463
	PR	.539	.286	.402	.251	.168	.581	.01555	.0099	.03594
	RPT	.539	.143	.226	.557	.123	.320	.0097	.00214	.0055
CS	DY	.297	.123	.228	.097	.284	.619	.00081	.00237	.00516
	SC	.297	.32	.355	.32	.123	.557	.0108	.00415	.0187
	RM	.297	.557	.418	.557	.123	.32	.03852	.00851	.02213
LTR	SER	.164	.32	.365	.33	.097	.619	.0063	.00186	.0018
	AW	.164	.557	.412	.123	.557	.32	.00463	.0209	.01204
	RT	.164	.123	.225	.123	.32	.557	.0056	.00145	.00253
								0.12408	0.05704	0.17843

III. CONCLUSION:

From our proposed model, the supplier C possesses the highest grade. Hence, from our project we select the supplier C as the best supplier. The major contribution of this project lies in the development of a comprehensive methodology, which incorporates diversified issues, for the selection of a supplier. The project also provides for a review of the issues, which influence the selection of a provider. The ANP approach, as a part of this methodology, not only leads to a logical result but also enables the decision-makers to visualize the impact of various criteria in the final result.

Further, we have demonstrated that the interdependencies among various criteria can be effectively captured using the ANP technique, which has rarely been applied in the context of outsourcing decisions.

At a time when outsourcing of supplier activities has become a global trend, this project provides an insight into the various aspects of supplier selection. The proposed methodology serves as a guideline to the logistics managers in outsourcing-related decisions. The ANP approach is capable of taking into consideration both qualitative and quantitative criteria. Similar ANP-based models may also be developed in other contexts as well. But, as the development and evaluation of these models demand significant time and efforts from the decision-makers in the formation of pair wise comparison matrices, these should be used for long-term strategic decisions only where the investments made in the lengthy and cumbersome process of decision- making are recovered in due course of time. Further, though the technique is computationally intensive, the benefits of risk reduction will outweigh the cost and time.

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