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Relationships among Supplier Selection Criteria using Interpretive Structural Modeling for Manufacturing Organization in Kerala

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ABSTRACT: *Supplier selection and evaluation is one of the most critical activities of purchasing department and the suppliers are considered as the best intangible assets of any organization. In modern management it needs to consider many factors other than quality, delivery and price for the evaluation of supplier with the aim of developing a long-term supplier relationship. This paper presents an approach to identify and rank the various criteria used for the supplier evaluation using interpretive structural modelling (ISM). The interactions among the criteria are analyzed for the supplier development using ISM. An empirical survey (sample size = 74) was conducted among engineering and electrical manufacturing industries in Kerala to investigate supplier selection criteria and its importance in the supplier selection process. An established structure of criteria is used to map criteria relationships inside organizations. ISM model uses 24 criteria for the supplier evaluation which were obtained as the most favored ones from the survey and finds the interactions and interdependence between the criteria and identifies the criteria which influence the most and the least for the evaluation of supplier. This ISM framework consists of ten levels in which criteria like 'Quantity discount', 'Conformance Quality', 'Warranties and Claim Policies' are at the top level and 'Technical' and 'R&D capabilities' are at the base level. The criteria 'Reputation and Position in the Industry' are having high driving power whereas 'Competitive Pricing' has high dependence power. Decision Makers can use the proposed framework to develop better relationships with suppliers and to create management responses that influence and improve their relationships with them. The study can be extended to other industrial sectors for a better understanding of how different factors influence supplier development.*

KEYWORDS: *Interpretive Structural Modelling, Manufacturing Industries, Supplier Selection*

I. INTRODUCTION

Supplier selection represents one of the most important decisions in a company to remain competitive, where markets are changing very fast. The purchasing activity is a significant component of the final cost of the product; therefore, supplier selection is one of the decisions which determine the long-term viability of the company. Gencer and Gurpinar [1] point out that the costs of the purchased goods and services account for more than 60% of the cost of goods sold in many firms and over 50% of all quality defects can be traced back to purchase material. The total cost will reduce considerably by reducing these costs, which mostly depend on the supplier. Hence, supplier selection becomes a very important requirement in the course of the flow of supply chain. Inefficiencies in a typical supply chain result in up to 25 % of a company's operating costs being wasted. In addition, wastage of 5 % throughout the supply chain can double a company's profit margin. Because of these significant economic differences, companies often provide much importance to their supply chains as to their production methods. Various methods and criteria are considered for this supplier evaluation process but the traditional concepts have been changed in recent years and new benchmarks have been established. Scenario is changing from the earlier concepts of selecting a supplier whose bids at lower price. So the criteria for evaluation have to be reconsidered and the large no: of criteria and their interrelationships makes supplier evaluation process more complex. The companies are looking for a unified model which can be treated as a better evaluation system through which a green channel system at inbound logistics can be made reality and cost reduction can be done at the supplier side. The objective of supplier selection process is to reduce purchase risk, maximize overall value to the purchaser, and develop closeness and long-term relationships between buyers and suppliers [2].The objectives of this study are, (i) to identify the most favored criteria for evaluating supplier and (ii) to establish a structure of inter-relationships among these criteria

II. LITERATURE REVIEW

Supplier selection and evaluation have become one of the major topics in production and operations management literature, especially in advanced manufacturing technologies and environment [3]. Supplier selection problem has become one of the most important issues for establishing an effective supply chain system. The supplier selection problem in a supply chain system is a group decision according to multiple criteria from which a number of criteria have been considered for supplier selection. The main objective of supplier selection process is to reduce purchase risk, maximize overall value to the purchaser, and develop closeness and long-term relationships between buyers and suppliers, which is effective in helping the company to achieve "Just-In-Time" (JIT) production [2]. Supplier selection is a multiple criteria decision-making (MCDM) problem which is affected by several conflicting factors. Consequently, a purchasing manager must analyze the trade-off between the several criteria.

The literature presents numerous techniques and approaches towards talking the supplier selection and evaluation problem such as Analytic hierarchy process, analytic network process, Topsis, ISM,etc. The Analytical Hierarchic Process (AHP) is a decision-making method for prioritizing alternatives when multiples criteria and sub-criteria must be used. Authors like Muralidharan [4], Chan [5] wrote about this topic and developed extensions of AHP approach to improve the model. The Analytic Network Process (ANP) is a generalization of the Analytic Hierarchy Process (AHP) and can be used to treat more sophisticated decision problem than the AHP .Three authors proposed ANP to solve the supplier selection problem: S Talluri and R C Baker [6]found that supplier evaluating factors would influence each other. An ISM model of vendor-managed inventory is developed by Dobler [7]. Kannan [8]analysed Supplier Development Criteria for An Automobile Industry by ISM methodology.Sarkar and Mohapatra wrote about the fuzzy set theory in the supplier selection process [9]. Interpretive structural modelling (ISM) methodology was utilized to understand the mutual influences among the barriers so that those driving barriers, which can aggravate few more barriers and those independent barriers, which are mostly influenced by driving barriers, are identified [10]. An increased attention for developing outbound logistics strategies for the supply chain was suggested.

ISM is well-proven for identifying the structural relationships among system specific variables, which define the problem under study proposed by Warfield in 1994. Its basic idea is to use experts' practical experience and knowledge to decompose a complicated system into several sub-systems (elements) and construct a multilevel structural model. ISM is a learning process that enables individuals or groups to develop a map of the complex relationships between the many elements involved in a complex situation [11]. ISM based approach is one of the versatile and robust technique that has been used for solving such complex multi-factorial problem. ISM is interpretive, as judgment of the selected group for the study decides whether and how the variables are related [12]. ISM is often used to provide fundamental understanding of complex situations, as well as to put together a course of action for solving a problem.

III. METHODOLOGY

The first objective of identifying the criteria for evaluating suppliers is done by a questionnaire survey, and the second objective for deriving the inferences by establishing the structure of inter-relationships among supplier criteria using ISM.First, an extensive literature review was done to identify the major criteria and sub criteria that have been used for the supplier selection process over the years. The criteria identified were shortlisted based on an expert opinion collection from 10 experts from various manufacturing industries having an average work experience of 10 years in this field. Forty eight criteria were found to be important criteria. A questionnaire were prepared incorporating this 48 criteria and the respondents were asked to rate the importance of each criteria on 5 point likert scale (1=very low importance 2= low importance 3=normal importance 4=high importance 5=very high importance). Convenience cum cluster sampling was used as the sampling plan. Normal plot and reliability analysis were carried out for the questionnaire validity check and reliability using SPSS (SPSS V.20, IBMCorporation). The mean for each criteria and sub criteria were calculated to identify its importance. Second, interpretive structural modeling (ISM) were done to determine the second objective "Interrelationships among the supplier selection criteria". ISM starts with an identification of elements which are relevant to the problem or issue and extends with a group problem-solving technique. A structural self-interaction matrix (SSIM) is developed based on pair-wise comparison of elements. In the next step, the SSIM is converted into a reachability matrix. Then, ISM model is derived by the partitioning of the elements. Based on the level obtained by reachability matrix, an initial digraph is obtained. In this development, the top level barrier is positioned at the top of the digraph and second level barrier is placed at second position and so on, until the bottom level is placed at the lowest position in the digraph. Next, the digraph is converted into an ISM model by

replacing nodes of the elements with statements. Fig.1 explains the logical flow of the process. The next sub-section presents the detailed ISM procedure.

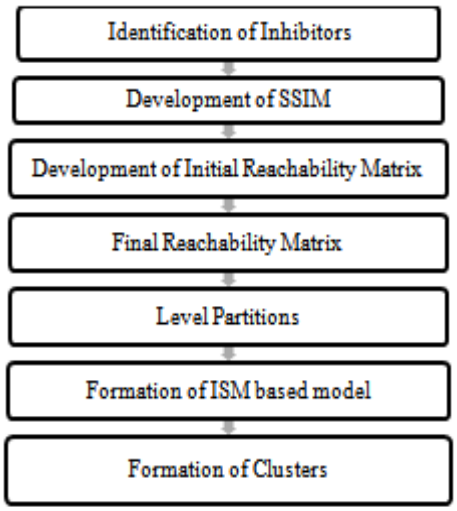

Figure 1: ISM methodology followed in the study

ISM procedure

Identification of inhibitors

The elements to be considered for relationship identification are obtained through literature surveyor by conducting a survey.

3.1.2Development of Structural Self-Interaction Metrics (SSIM*)*

Development of interpretive structural model starts with the preparation of a structural self-interaction matrix, which shows the direction of contextual relationships among the elements. In developing SSIM, following four symbols have been used to denote the direction of relationship between two barriers i and j. Table 1 shows the rules for forming SSIM.

Table 1: Rules for forming SSIM

Symbol	Relationship between row (i) and column (j) elements
V	Barrier i will lead to barrier j , not in reverse direction
A	Barrier j will lead to barrier i , not in reverse direction
X	Barrier i and j will lead to each other, in both directions
O	Barrier i and j are unrelated

Initial Reachability Matrix

This is a metrics of only binary elements. The SSIM has been converted in to a binary matrix, named Reachability Matrix by substituting V, A, X, O by 1 or 0 applying the following rules:

- If (i, j) value in the SSIM is V, (i, j) value in the reachability matrix will be 1 and (j, i) value will be 0
- If (i, j) value in the SSIM is A, (i, j) value in the reachability matrix will be 0 and (j, i) value will be 1
- If (i, j) value in the SSIM is X,(i, j) value in the reachability matrix will be 1 and (j, i) value will also be 1
- If (i, j) value in the SSIM is O,(i, j) value in the reachability matrix will be 0 and (j, i) value will also be 0

By applying these rules, initial reachability matrix for the barriers can been obtained

3.1.4Final Reachability Matrix*:*

The final reachability matrix for the criteria are obtained by incorporating the transitivity. The transitivity of the contextual relation is a basic assumption made in ISM. It states that: if criteria 1 is related to 2, and criteria 2 is related to 3, then the criterion 1 is necessarily related to 3. The driving power and the dependence power of

each barrier have also been shown here.Driving power and dependence power are calculated by adding the number of ones in the rows and columns of each barrier respectively. These driving power and dependence help to classify the inhibitors into four clusters.

3.1.5Partitioning of Levels*:*

The reachability and antecedent set for each barrier have been determined from the final reachability matrix. The reachability set for a barrier consists of the barrier itself and the other barriers, which it influences. The antecedent set consists of the barrier itself and other barriers, which may influence it. The variables, which are common in reachability set and antecedent set, are allocated at the intersection set. Thus, antecedent set and intersection set are located. This leads to locate the top-level element. The top-level element for each hierarchy is the elements in which antecedent set and intersection set are same in the ISM hierarchy. Once the top level barrier is identified, it is removed from consideration and other top level barriers are found. This process will be continued till all levels of each barrier are found. The levels identified by this procedure have been utilized for the formation of ISM Model

3.1.6.Formation of ISM based model*:*

From the reachability metrics, a preliminary model, called digraph, has been developed by means of vertices or nodes, and lines of edges (Jharkaria& Shankar, 2005). The digraph is converted into the final ISM model by replacing the criteria nodes with statements. The ISM based model is reviewed for conceptual inconsistency and the final model is presented in Figure 2. The relationship between the barriers j and i is shown by an arrow pointing from i to j.

3.1.7Cluster Formation*:*

Matriced' Impactscroises-multipicationappliqu´eanclassment (cross-impact matrix multiplication applied to classification) is abbreviated as MICMAC, developed by Michel Godet in 1975. The purpose of a MICMAC analysis is to analyse the driver and dependence power of the barriers. This is done to identify the key barriers that drive the system. All barriers are classified based on driving and dependence power analysis into four clusters; autonomous, dependent, linkage and independent criteria. Here the driving power and dependence of barriers are determined from the reachability matrix. The first cluster consists of the "autonomous barriers" that have weak driver power and weak dependence. These barriers are relatively disconnected from the system, with which they have only few links, which may be strong. The second cluster consists of the dependent barriers that have weak driver power but strong dependence. Third cluster has the linkage barriers that have strong driving power but also strong dependence. These barriers are unstable in the fact that any action on these barriers will have an effect on the others and also a feedback on themselves. The fourth cluster includes the independent barriers having strong driving power but weak dependence. It is observed that a variable with a very strong driving power, called the key variables, falls into the category of independent or linkage barriers.

IV. RESULTS AND DISCUSSIONS

4.1 Identification of inhibitors

Seventy eight supplier selection criteria are identified from the literature [13] published till date. Then the prim facia important 47 supplier selection criteria relevant to the electrical and engineering manufacturing industries are identified from the opinion of a panel of Experts by conducting a pilot survey. A questionnaire is prepared incorporating this 47 criteria and Experts are asked to indicate the importance of 47 listed barriers on a five-point Likert scale, where 1 stands for 'very low importance' and 5 for 'very high importance'. Those barriers that have mean value greater than 60% of its maximum value (i.e., 3) are considered as critical criteria for supplier selection in electrical and engineering manufacturing industries. The population was selected from the Annual Survey of Industries Report 2011-12[14]. Sample size was 74 and response rate was 24.4%. From the survey [15].24 barriers are identified as the most critical criteria relevant to the industry under study and are given in Table 2. The mean of the data collected are calculated using SPSS software. The reliability of the data collected from the survey is measured using Cronbach's alpha- coefficient. The value obtained 0.781 is considered as acceptable reliability. The critical criteria are listed in the table along with the mean scores.

Interrelationship among the supplier selection criteria

Identification of the inhibitors

The critical criteria for supplier selection are selected and the details have been highlighted in the above section and the criteria are listed in Table 2. The results of subsequent steps are presented below.

Development of Structural Self-Interaction Metrics (SSIM:

Table 3 shows the structural self-interaction matrix. This shows the direction of contextual relationships among the elements is prepared. The reliability of the responses from experts is tested by calculating Cronbach's alpha value (α = .935). The value obtained indicates high reliability and is acceptable.

The meaning of each symbol is illustrated below

- V - Barrier i will lead to barrier j , not in reverse direction
- A - Barrier j will lead to barrier i , not in reverse direction
- X - Barrier i and j will lead to each other, in both directions
- O - Barrier i and j are unrelated

Initial Reachability Matrix*:*

Table 3 shows the initial reachability matrix for the barriers. Here V, A, X, O are replaced by binary values 1 and 0 according to the condition mentioned in the 4.1.The value 1 indicates that the criteria are interrelated either from i to j or j to i or in both sides.0 shows that there are no relationship between the elements.

Final Reachability Matrix *:* The final reachability matrix for the criteria obtained by incorporating the transitivity is shown in Table 4. The driving and dependence power are also highlighted in them. Driving power and dependence power are calculated by adding the number of ones in the rows and columns of each barrier respectively. These driving power and dependence help to classify the inhibitors into four clusters. Ranks of the criteria based on their driver powers indicate that *Reputation and Position in Industry, R&D, Technical capability and Flexibility* are the major drivers and the Ranks of the criteria based on their dependence powers indicate that *Competitive Price* and*Conformance Quality* are the dependence powers.

Table 2: Mean Scores of Critical Criteria

No	Sub Criteria	Mean
1	Transportation Cost	3.85
2	Quantity Discount	4.28
3	Competitive Price	4.31
4	On time Delivery	4.54
5	Short Lead time	4.21
6	Information	3.18
7	Conformance Quality	4.54
8	Low Return Rate	4.15
9	ISO certified	3.67
10	After sales service	4.35
11	Warranties and claim policies	3.52
12	Financial Position	4.23
13	Credit Strength	3.76
14	Envt Protection System Certification	3.53
15	R & D Capability	3.64
16	Technical Capability	3.68
17	Long term relationship	3.95
18	Performance history	3.81
19	Political	3.3
20	Order Delays	3.81
21	Reputation and position in industry	3.88
22	Geographical Location	3.32
23	E Transaction Capability	3.4
24	Flexibility	3.88

Partitioning of Levels : In the present work, the twenty four supplier selection criteria, along with their reachability set, antecedent set, intersection set and levels, are calculated. Level identification process of these barriers can be completed in ten iterations, which can be summarized as Table 6.Criteria like *R&D capability and Technical Capability* forms the tenth level and they forms the base of the hierarchy. *Conformance Quality, Quantity discount* are the level 1 criteria all other levels are placed between this.

Table 3:Structural Self Interaction Matrix

Criteria	Sub Criteria	No:	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
A	Transportation Cost	1	O	X	O	A	O	X	A	A	A	A	A	O	A	V	V	O	O	V	A	X	V	X	A	
A	Quantity Discount	2	0	X	0	O	A	O	0	X	X	O	O	X	X	O	O	O	O	O	O	O	O	X		
A	Competitive Price	3	O	X	O	A	A	X	O	O	X	X	O	O	A	X	O	O	O	X	A	O	O			
B	On time Delivery	4	O	A	O	A	A	X	A	0	0	0	0	0	0	0	0	0	0	X	X	X				
B	Short Lead time	5	O	A	A	A	O	X	0	0	0	0	0	0	0	0	0	0	0	0	A					
B	Delivery Information	6	O	X	A	O	A	V	O	O	A	A	O	O	O	O	X	X	V	V						
C	Conformance Quality	7	X	X	A	O	A	O	O	A	X	A	A	O	O	V	O	A	X							
C	Low Return Rate	8	O	O	O	O	V	O	O	A	X	A	A	O	O	O	O	O								
C	ISO certified	9	X	O	O	O	V	O	O	O	V	A	A	O	O	O	O									
D	After sales service	10	O	A	O	A	X	O	O	X	X	A	A	O	O	X										
D	Warranties and claim policies	11	O	A	O	O	A	O	O	O	X	O	O	O	O											
E	Financial Position	12	O	V	V	O	V	O	O	O	A	A	A	A												
E	Credit Strength	13	O	A	O	O	A	O	O	O	A	O	O													
F	R & D Capability	14	V	V	V	O	O	V	O	O	O	X														
F	Technical Capability	15	V	V	V	O	O	V	O	O	O															
G	Long term relationship	16	O	X	O	O	A	V	O	V																
G	Performance history	17	O	O	O	O	X	A	O																	
H	Political	18	O	O	O	A	X	O																		
H	Order Delays	19	O	O	A	A	X																			
I	Reputation and position in industry	20	A	X	A	A																				
I	Geographical Location	21	O	X	O																					
J	E Transaction Capability	22	O	X																						
J	Flexibility	23	V																							
J	Envt Protection System Certification	24																								

Note: V-Barrier i lead to j ,A-Barrier j lead to I, X-Interrelated ,O-unrelated

Formation of ISM based model

Figure 3 shows the final ISM developed. In this development, the top level factor (Criteria 2, 7,11,19) is positioned at the top of the model and second level factor (Criteria 3,5,10,24) is placed at second position and so on, until the bottom level (Criteria13, 14, 15) is placed at the lowest position. *R&D Capability, Technical capability and credit strength* are the driver criteria and they forms the base of the hierarchy. Top level criteria are the criteria results from the lower level elements and they are the dependent one and depicts the successful supplier selection. The bottom levels leads to next level and continues and reaches the top level. Suppliers should works on lower elements to achieve top level elements and that are evaluated by manufacturers

Table 4: Initial ReachabilityMatrix

Criteria	Sub Criteria	No:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
A	Transportation Cost	1	1	0	1	1	1	0	1	0	0	1	1	0	0	0	0	0	0	0	1	0	0	0	1	0
A	Quantity Discount	2	1	1	1	0	0	0	0	0	0	0	0	1	1	0	0	1	1	0	0	0	0	0	1	0
A	Competitive Price	3	1	1	1	0	0	0	1	0	0	0	1	0	0	0	1	1	0	0	1	0	0	0	1	0
B	On time Delivery	4	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
B	Short Lead time	5	1	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
B	Delivery Information	6	1	0	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	1	0	0	0	1	0
C	Conformance Quality	7	0	0	1	1	0	0	1	1	0	0	1	0	0	0	0	1	0	0	0	0	0	0	1	1
C	Low Return Rate	8	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0
C	ISO certified	9	0	0	0	0	0	1	1	0	1	0	0	0	0	0	0	1	0	0	0	1	0	0	0	1
D	After sales service	10	0	0	0	0	0	1	0	0	0	1	1	0	0	0	0	1	1	0	0	1	0	0	0	0
D	Warranties and claim policies	11	0	0	1	0	0	0	0	0	0	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0
E	Financial Position	12	1	1	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	1	1	0
E	Credit Strength	13	0	1	0	0	0	0	0	0	0	0	0	1	1	0	0	1	0	0	0	1	0	0	1	0
F	R & D Capability	14	1	0	0	0	0	0	1	1	1	1	0	1	0	1	1	0	0	0	1	0	0	1	1	0
F	Technical Capability	15	1	0	1	0	0	1	1	1	1	1	0	1	0	1	1	0	0	0	1	0	0	1	1	1
G	Long term relationship	16	1	1	1	0	0	1	1	1	0	1	1	1	1	0	0	1	1	0	1	0	0	0	1	0
G	Performance history	17	1	1	0	0	0	0	1	1	0	0	0	0	0	0	0	0	1	0	1	1	0	0	0	0
H	Political	18	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	0	0	0
H	Order Delays	19	1	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	1	1	0	0
I	Reputation and position in industry	20	0	1	1	1	0	1	1	0	0	1	1	0	1	0	0	1	1	1	1	1	1	1	1	1
I	Geographical Location	21	1	0	1	1	1	0	0	0	0	1	0	0	0	0	0	0	0	1	1	1	1	0	1	0
J	E Transaction Capability	22	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	1	1	0	0	1	1	0
J	Flexibility	23	1	1	1	1	1	1	1	0	0	1	1	1	0	0	0	1	0	0	0	1	1	1	1	1
J	Envt Protection System Certification	24	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1

Formation of Clusters : Cluster formation is done based on the driving power and dependence of barriers which are determined from the reachability matrix .A graph between dependence power and driving power of the barriers is presented in Fig.3 Barriers are classified based on driving and dependence power analysis into four clusters; autonomous, dependent, linkage and independent criteria. *Low return rate, ISO certification, Political risk and Environmental Protection system* falls into autonomous criteria, this indicates that these criteria may not influence the supplier selection in the electrical industries. It is also observed that *Quantity discount, On time delivery, After sales service, short lead time* is having weak drivers but strongly dependent on other criteria. The management should place a high priority in tackling the criteria, which have a high-driving power, and thus, possessing the capability to influence other criteria, It is also observed from the ISM model that *financial position, credit strength* and *Technical capability* have strong driver power and therefore, these are less dependent on the other criteria. Thus, it can be inferred that these are strong drivers and may be treated as the root cause of remaining criteria. To develop these criteria, a comprehensive strategic plan for supplier development should to be initiated to achieve success. Linkage barriers are *Transportation cost, Competitive price, conformance quality*, etc. any action on this criteria may influence others since they are unstable in nature

Table 5: Final Reachability Matrix

Criteria	Sub Criteria	No:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Driver
A	Transportation Cost	1	1	1*	1	1	1	1*	1	1*	0	1	1	1*	0	0	0	1*	0	0	1	1*	0	0	1	0	**15**
A	Quantity Discount	2	1	1	1	0	0	0	1*	0	0	0	1*	1	1	0	0	1	1	0	1*	1*	0	0	1	0	**12**
A	Competitive Price	3	1	1	1	0	0	1*	1	0	0	1*	1	1*	0	0	1	1	0	0	1	0	1*	1*	1	1*	**15**
B	On time Delivery	4	1*	0	1*	1	1	1	1	0	0	0	0	0	0	0	0	1*	0	0	1	0	0	0	0	0	**8**
B	Short Lead time	5	1	0	1*	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	**5**
B	Delivery Information	6	1	1*	1	1	1	1	1	1	0	0	1*	0	0	0	0	1*	1*	0	1	1*	1*	1*	1	1*	**17**
C	Conformance Quality	7	1*	1*	1	1	0	1*	1	1	0	1*	0	1*	0	0	0	1	0	0	1*	1*	0	0	1	1	**14**
C	Low Return Rate	8	0	1*	1*	1*	0	0	1	1	0	1*	1*	0	0	0	0	1	0	0	1*	1	0	0	0	0	**10**
C	ISO certified	9	0	0	1*	1*	0	1	1	0	1	1*	0	0	0	0	0	1	0	0	0	1	0	0	1*	1	**10**
D	After sales service	10	0	0	1*	0	0	1	1*	1*	0	1	1	0	0	0	0	1	1	0	1*	0	0	0	1*	0	**10**
D	Warranties and claim policies	11	1*	1*	1	0	0	0	0	0	0	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0	**6**
E	Financial Position	12	1	1	1	1*	1*	1*	1*	0	0	1*	1*	1	0	0	0	1*	0	0	1*	1	0	1	1	0	**15**
E	Credit Strength	13	1*	1	1*	0	0	1*	1*	0	0	1*	1*	1*	1	0	0	1	0	0	0	1	0	1*	1	0	**13**
F	R & D Capability	14	1	0	1*	1*	1*	1*	1	1	1	1	1*	1	0	1	1	1*	0	0	1	1*	0	1	1	1*	**19**
F	Technical Capability	15	1	1*	1	1*	1*	1	1	1	0	1	1*	1	0	1	1	1*	0	0	1	1*	0	1	1	1	**19**
G	Long term relationship	16	1	1	1	0	1*	1	1	1	0	1	1	1	1	0	0	1	1	0	1	1*	0	0	1	0	**16**
G	Performance history	17	1	1	1*	1*	0	0	1	1	0	0	1*	0	0	0	0	1*	1	0	1	1	0	0	1*	0	**12**
H	Political	18	1	0	1*	1	1*	0	1*	0	0	0	0	0	0	0	0	0	0	1	1*	1	1	0	1*	0	**10**
H	Order Delays	19	1	1*	1	1	0	0	1*	0	0	1*	1*	0	0	0	0	0	1	1*	1	0	1	1	1*	0	**13**
I	Reputation and position in industry	20	1*	1	1	1	1*	1	1	1*	0	1	1	1*	1	0	0	1	1	1	1	1	1	1	1	1	**21**
I	Geographical Location	21	1	1*	1	1	1	1*	1*	0	0	1	1*	0	0	0	0	1*	1*	1	1	1	1	0	1	0	**16**
J	E Transaction Capability	22	1*	0	1*	1*	1	1	1	0	0	0	0	0	0	0	0	0	0	1	1	1*	1*	1	1	0	**12**
J	Flexibility	23	1	1	1	1	1	1	1	1*	0	1	1	1	0	0	0	1	1*	0	1*	1	1	1	1	1	**19**
J	Envt Protection System Certification	24	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	1*	0	0	0	1	0	0	0	1	**5**
		Depen	**20**	**16**	**23**	**17**	**13**	**16**	**22**	**11**	**3**	**16**	**17**	**11**	**4**	**2**	**3**	**20**	**9**	**5**	**20**	**18**	**8**	**10**	**19**	**9**	

Note: * Values after transitivity

Table 6: Partitioning of Levels

Criteria	Reachability Set	Antecedent Set	Intersection Set	Level
1	1 2 3 4 5 6 7 8 10 11 12 16 19 20 23	1 2 3 4 5 6 7 11 12 13 14 15 16 17 18 19 20 21 22 23	1 2 3 4 5 6 7 11 12 16 19 20 23	III
2	1 2 3 7 11 12 13 16 17 19 20 23	1 2 3 6 7 8 11 12 13 15 16 17 19 20 21 23	1 2 3 7 11 12 13 16 17 19 20 23	I
3	1 2 3 6 7 10 11 12 15 16 19 21 22 23 24	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23	1 2 3 6 7 10 11 12 15 16 19 21 22 23	II
4	1 3 4 5 6 7 16 19	1 4 5 6 7 8 9 12 14 15 17 18 19 20 21 22 23	1 4 5 6 7 19	III
5	1 3 4 5 19	1 4 5 6 12 14 15 16 18 20 21 22 23	1 4 5	II
6	1 2 3 4 5 6 7 8 11 16 17 19 20 21 22 23 24	1 3 4 6 7 9 10 12 13 14 15 16 20 21 22 23	1 3 4 6 7 16 20 21 22 23	IV
7	1 2 3 4 6 7 8 10 12 16 19 20 23 24	1 2 3 4 6 7 8 9 10 12 13 14 15 16 17 18 19 20 21 22 23 24	1 2 3 4 6 7 8 10 12 16 19 20 23 24	I
8	2 3 4 7 8 10 11 16 19 20	1 6 7 8 10 14 15 16 17 20 23	7 8 10 16 20	III
9	3 4 6 7 9 10 16 20 23 24	9 14 24	9 24	V
10	3 6 7 8 10 11 16 17 19 23	1 3 7 8 9 10 11 12 13 14 15 16 19 20 21 23	3 7 8 10 11 16 23	II
11	1 2 3 10 11 16	1 2 3 6 8 10 11 12 13 14 15 16 17 19 20 21 23	1 2 3 10 11 16	I
12	1 2 3 4 5 6 7 10 11 12 16 19 20 22 23	1 2 3 7 12 13 14 15 16 20 23	1 2 3 7 12 20 23	IX
13	1 2 3 6 7 10 11 12 13 16 20 22 23	2 13 16 20	2 13 16 20	X

14	1 3 4 5 6 7 8 9 10 11 12 14 15 16 19 20 22 23 24	14 15	14 15	X
15	1 2 3 4 5 6 7 8 10 11 12 14 15 16 19 20 22 23 24	3 14 15	3 14 15	X
16	1 2 3 5 6 7 8 10 11 12 13 16 17 19 20 23	1 2 3 4 6 7 8 9 10 11 12 13 14 15 16 17 20 21 23 24	1 2 3 6 7 8 10 11 12 16 17 20 23	III
17	1 2 3 4 7 8 11 16 17 19 20 23	2 6 10 16 17 19 20 21 23	2 6 17 19 20 23	V
18	1 3 4 5 7 18 19 20 21 23	18	18	VII
19	1 2 3 4 7 10 11 17 18 19 21 22 23	1 2 3 4 5 6 7 8 10 12 14 15 16 17 18 19 20 21 22 23	1 2 3 4 7 10 11 17 18 19 21 22 23	I
20	1 2 3 4 5 6 7 8 10 11 12 13 16 17 18 19 20 21 22 23 24	1 2 6 7 8 9 12 13 14 15 16 17 18 20 21 22 23 24	1 2 6 7 8 12 13 16 17 18 20 21 22 23 24	III
21	1 2 3 4 5 6 7 10 11 16 17 18 19 20 21 23	3 6 18 19 20 21 22 23	3 6 18 19 20 21 23	VI
22	1 3 4 5 6 7 18 19 20 21 22 23	3 6 12 13 14 15 19 20 22 23	3 6 19 20 22 23	VIII
23	1 2 3 4 5 6 7 8 10 11 12 16 17 19 20 21 22 23 24	1 2 3 6 7 9 10 12 13 14 15 16 17 18 19 20 21 22 23	2 3 6 7 10 12 16 17 19 20 21 22 23	III
24	7 9 16 20 24	3 6 7 9 14 15 20 23 24	7 9 20 24	II

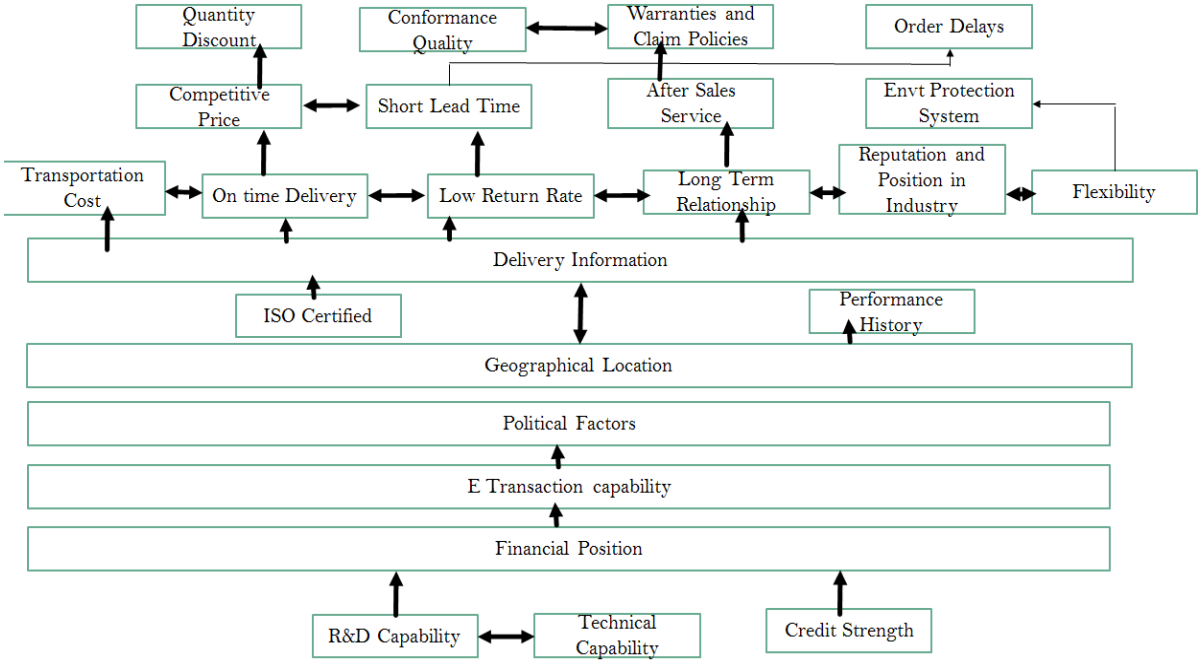

Figure 2: ISM model for the manufacturing industries in Kerala

The resultscan be summarized as follows

ISM model shows that there are ten levels of criteria are to be considered for well-defined supplier selection method whereas the earlier study about supplier selection using ISM discussed only about the six levels. This increase in number of levels shows the increase in complexity of supplier selection over years. Hence manufacturers are considering much more criteria and analysis for choosing the right supplier. The criteria like *Quantity discount, conformance quality* are at the top level of the hierarchy with higher dependence power.

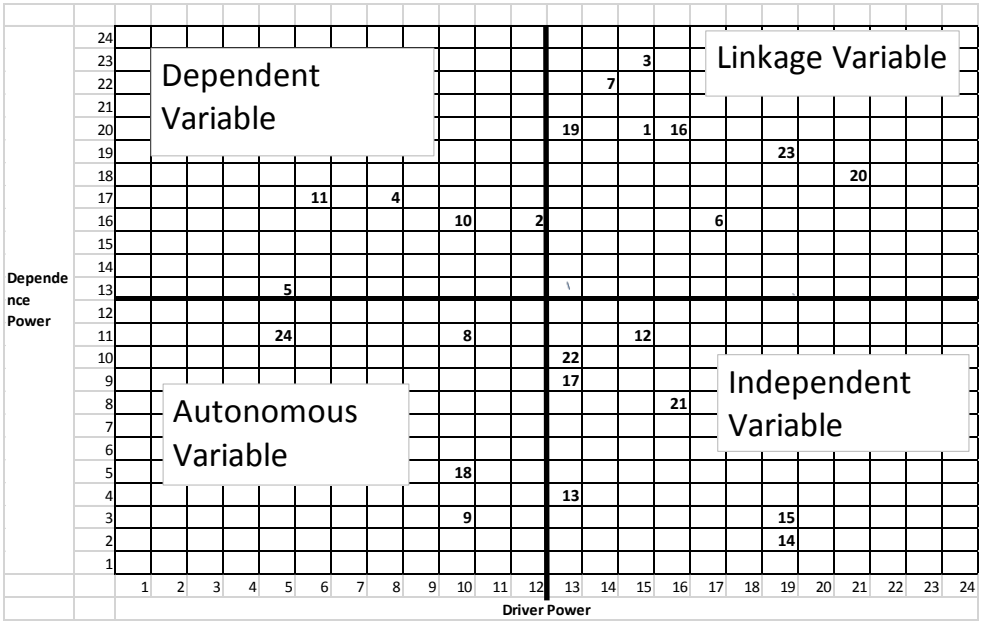

Figure 3: Driver Dependence Power Matrix

These criteria were having high mean scores during survey analysis and they are the top level since this are the criteria where manufacturers prim facially evaluates the supplier. But the survey and model shows that manufacturers consider much more criteria's of supplier like *facilities and capabilities,financial position*. These criteria were having strong driver power and therefore these are less dependent on the other criteria.Thus it can be inferred as the root cause of the remaining criteria and forms the base of the hierarchy. The actions on lower level helpsto achieve the higher levels. Driver Dependence power matrix indicates that there are five autonomous criteria and can be inferred that this criteria may not influence the supplier selection in Kerala. Also the linkage variable like *Transportation cost, competitive price* are the criteria with higher driver power and dependence power should be treated with utmost care since the actions on such variable may affect other since they are unstable in nature .Comparing the results of this work with earlier one done at northern side it is observed that transportation cost is comparatively having higher mean scores, dependence power. The criteria*Transportation Cost* is of high importance in this study because this study is done at Kerala industries and the most suppliers to Kerala are belongs to northern side and this criteria is a cost addition element. ISM model helps to identify the interrelationships and importance of each criteria whereas survey only identified those criteria. Top level criteria are considered mainly by manufacturers where the supplier can work on the lower levels to achieve the top level criteria.

V CONCLUSION AND RECOMMENDATIONS

Survey among electrical and engineering industries identified 24 critical criteria for supplier selection and in which *Conformance quality* and *On time delivery* are the major ones. ISM-based model proposed in this work for identification of criteria of supplier development can provide the decision maker a more realistic representation of the problem in the course of supplier selection. In this work, using the ISM methodology, a relationship model among the supplier selection criteria in electrical and engineering industries has been developed. The utility of the proposed ISM methodology in imposing order and direction on the complexity of relationships among elements of the supplier evaluation system assumes tremendous value to the decision makers. The limitation of the study is that ISM model has not been statistically validated and weightage for each criteria are not determined .The weightage determination using appropriate tools like ANP and the integrated ISM model can be alternatively tested from the results of an independent structural equation modeling.

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