Research Journal of Management Sciences ISSN 2319–1171
Vol. **2(2),** 3-8, February **(2013)** *Res. J. Management Sci.*

Interpretive Structural Modelling (ISM) approach: An Overview

Rajesh Attri[1], Nikhil Dev[1] and Vivek Sharma[2]
[1]Department of Mechanical Engineering, YMCA University of Science and Technology, Faridabad, INDIA
[2]Department of Mechanical Engineering, Advanced Institute of Technology and Management, Palwal, INDIA

Available online at: www.isca.in
Received 27th November 2012, revised 27th January 2013, accepted 1st February 2013

Abstract

Interpretive structural modelling (ISM) is a well-established methodology for identifying relationships among specific items, which define a problem or an issue. This approach has been increasingly used by various researchers to represent the interrelationships among various elements related to the issue. ISM approach starts with an identification of variables, which are relevant to the problem or issue. Then a contextually relevant subordinate relation is chosen. Having decided the contextual relation, a structural self-interaction matrix (SSIM) is developed based on pairwise comparison of variables. After this, SSIM is converted into a reachability matrix (RM) and its transitivity is checked. Once transitivity embedding is complete, a matrix model is obtained. Then, the partitioning of the elements and an extraction of the structural model called ISM is derived. In this paper, key concept of ISM approach is discussed in detail.

Keywords: ISM, SSIM, RM, variable, modelling.

Introduction

It is generally felt that individuals or groups encounter difficulties in dealing with complex issues or systems. The complexity of the issues or systems is due to the presence of a large number of elements and interactions among these elements. The presence of directly or indirectly related elements complicates the structure of the system which may or may not be articulated in a clear fashion. It becomes difficult to deal with such a system in which structure is not clearly defined. Hence, it necessitates the development of a methodology which aids in identifying a structure within a system. Interpretive structural modelling (ISM) is such a methodology[1].

ISM is defined as a process aimed at assisting the human being to better understand what he/she believes and to recognise clearly what he/she does not know. Its most essential function is organisational. The information added (by the process) is zero. The value added is structural[2]. The ISM process transforms unclear, poorly articulated mental models of systems into visible and well-defined models.

Interpretive structural modelling (ISM): ISM is an interactive learning process. In this technique, a set of different directly and indirectly related elements are structured into a comprehensive systematic model[3,4]. The model so formed portrays the structure of a complex issue or problem in a carefully designed pattern implying graphics as well as words[1, 5, 6, 7].

Interpretive structural modeling (ISM) is a well-established methodology for identifying relationships among specific items, which define a problem or an issue[8]. For any complex problem under consideration, a number of factors may be related to an issue or problem. However, the direct and indirect relationships between the factors describe the situation far more accurately than the individual factor taken into isolation. Therefore, ISM develops insights into collective understandings of these relationships.

ISM starts with an identification of variables, which are relevant to the problem or issue, and then extends with a group problem-solving technique. Then a contextually relevant subordinate relation is chosen. Having decided on the element set and the contextual relation, a structural self-interaction matrix (SSIM) is developed based on pairwise comparison of variables. In the next step, the SSIM is converted into a reachability matrix (RM) and its transitivity is checked. Once transitivity embedding is complete, a matrix model is obtained. Then, the partitioning of the elements and an extraction of the structural model called ISM is derived[9].

In this approach, a systematic application of some elementary notions of graph theory is used in such a way that theoretical, conceptual and computational leverage are exploited to explain the complex pattern of contextual relationship among a set of variables. ISM is intended for use when desired to utilise systematic and logical thinking to approach a complex issue under consideration[10].

Interpretive Structural Modeling is a computer-aided method for developing graphical representations of system composition and structure. ISM had its inception in Warfield's[4] perception of the need, when attempting to couple science to policy, for "a set of communication tools which have both a scientific and lay character serving as a linkage mechanism between science and the public, and having meaning for all who are involved" and which, in particular, are capable of communicating a holistic sense of the elements and their relations which define system structure.

Warfield[4] stipulates a set of requirements for these communication tools which include i. Provision for the inclusion of the scientific elements ii. Means for exhibiting a complex set of relations iii. Means for showing that complex set of relations which permit continuous observation, questioning and modification of the relations iv Congruence with the originators' perceptions and analytical processes v. Ease of learning by public (or, by inference, multidisciplinary) audience.

Graphical models or, more specifically, directed graphs (digraphs) appear to satisfy these requirements. In such a representation, the elements or components of a system are represented by the "points" of the graph and the existence of a particular relationship between elements is indicated by the presence of a directed line segment. It is this concept of relatedness in the context of a particular relationship which distinguishes a system from a mere aggregation of components[11].

Characteristics of ISM: This methodology is interpretive as the judgment of the group decides whether and how the different elements are related. It is structural on the basis of mutual relationship; an overall structure is extracted from the complex set of elements. It is a modeling technique, as the specific relationships and overall structure are portrayed in a digraph model. It helps to impose order and direction on the complexity of relationships among various elements of a system[3, 6]. It is primarily intended as a group learning process, but individuals can also use it.

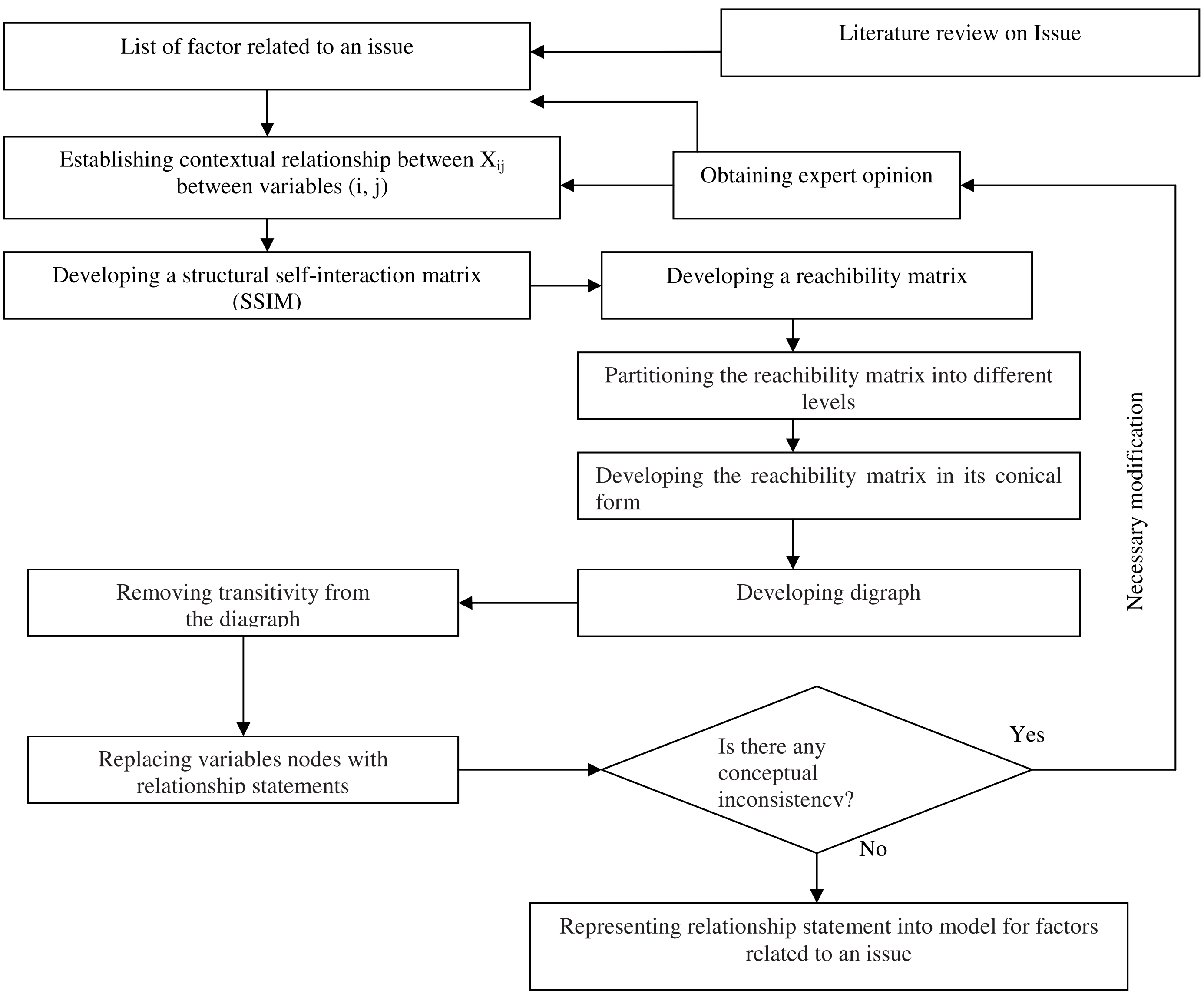

Figure-1
Flow diagram for preparing ISM model

Steps involved in ISM methodology: Warfield[4] developed a methodology that uses systematic application of some elementary notions of graph theory and Boolean algebra in such a way that when implemented in a man machine interactive mode, theoretical, conceptual and computational leverage is exploited to construct directed graph (a representation of the hierarchical structure of the system). This methodology has at least two desirable properties when compared to the similar approaches namely simplicity in the sense of not requiring from the user i.e. viewpoint of advance mathematical knowledge and efficiency in terms of economizing in computer time.

The various steps involved in ISM modeling are as follows: i. Identify the elements which are relevant to the problem. This could be done by a survey or group problem solving technique. ii. Establish a contextual relationship between elements with respect to which pairs of elements would be examined. iii. Develop a structural self-interaction matrix (SSIM) of elements. This matrix indicates the pair-wise relationship among elements of the system. This matrix is checked for transitivity. iv. Develop a reachability matrix from the SSIM. v. Partition the reachability matrix into different levels. vi. Convert the reachability matrix into conical form. vii. Draw digraph based on the relationship given in reachability matrix and remove transitive links. viii. Convert the resultant digraph into an ISM-based model by replacing element nodes with the statements. ix. Review the model to check for conceptual inconsistency and make the necessary modifications.

Various steps involved in ISM technique are illustrated in figure 1. The various steps, which lead to the development of an ISM model, are illustrated below.

Step 1: Structural Self-Interaction Matrix (SSIM): ISM methodology suggests the use of the expert opinions based on various management techniques such as brain storming, nominal group technique, etc. in developing the contextual relationship among the variables[10,12,13]. For this purpose, experts from the industry and academia should be consulted in identifying the nature of contextual relationship among the factors. These experts from the industry and academia should be well conversant with the problem under consideration. For analysing the factors, a contextual relationship of 'leads to' or 'influences' type must be chosen. This means that one factor influences another factor. On the basis of this, contextual relationship between the identified factors is developed.

Keeping in mind the contextual relationship for each factor and the existence of a relationship between any two factors (i and j), the associated direction of the relationship is questioned. The following four symbols are used to denote the direction of relationship between two factors (i and j): (a) V for the relation from factor i to factor j (i.e., factor i will influence factor j) (b) A for the relation from factor j to factor i (i.e., factor i will be influenced by factor j) (c) X for both direction relations (i.e., factors i and j will influence each other) (d) O for no relation between the factors (i.e., barriers i and j are unrelated).

Based on the contextual relationships, the SSIM is developed. To obtain consensus, the SSIM should be further discussed by a group of experts. On the basis of their responses, SSIM must be finalised.

Step 2: Reachability Matrix: The next step in ISM approach is to develop an initial reachability matrix from SSIM. For this, SSIM is converted into the initial reachability matrix by substituting the four symbols (i.e., V, A, X or O) of SSIM by 1s or 0s in the initial reachability matrix.

The rules for this substitution are as follows: (a) 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. (b) If the (i, j) entry in the SSIM is A, then the (i, j) entry in the matrix becomes 0 and the (j, i) entry becomes 1. (c) If the (i, j) entry in the SSIM is X, then the (i, j) entry in the matrix becomes 1 and the (j, i) entry also becomes 1. (d) If the (i, j) entry in the SSIM is O, then the (i, j) entry in the matrix becomes 0 and the (j, i) entry also becomes 0.

Following these rules, the initial reachability matrix is prepared. 1* entries are included to incorporate transitivity to fill the gap, if any, in the opinion collected during development of structural self-instructional matrix. After incorporating the transitivity concept as described above, the final reachability matrix is obtained.

Step 3: Level partitions: From the final reachability matrix, for each factor, reachability set and antecedent sets are derived. The reachability set consists of the factor itself and the other factor that it may impact, whereas the antecedent set consists of the factor itself and the other factor that may impact it. Thereafter, the intersection of these sets is derived for all the factors and levels of different factor are determined. The factors for which the reachability and the intersection sets are the same occupy the top level in the ISM hierarchy. The top-level factors are those factors that will not lead the other factors above their own level in the hierarchy. Once the top-level factor is identified, it is removed from consideration. Then, the same process is repeated to find out the factors in the next level. This process is continued until the level of each factor is found. These levels help in building the diagraph and the ISM model.

Step 4: Conical matrix: Conical matrix is developed by clustering factors in the same level across the rows and columns of the final reachability matrix. The drive power of a factor is derived by summing up the number of ones in the rows and its dependence power by summing up the number of ones in the columns[14, 15, 16]. Next, drive power and dependence power ranks are calculated by giving highest ranks to the factors that have the maximum number of ones in the rows and columns, respectively.

Step 5: Digraph: From the conical form of reachability matrix, the preliminary digraph including transitive links is obtained. It is generated by nodes and lines of edges[7,14, 15,16]. After removing the indirect links, a final digraph is developed. A digraph is used to represent the elements and their interdependencies in terms of nodes and edges or in other words digraph is the visual representation of the elements and their interdependence[17,18]. In this development, the top level factor is positioned at the top of the digraph and second level factor is placed at second position and so on, until the bottom level is placed at the lowest position in the digraph.

Step 6: ISM Model: Digraph is converted into an ISM model by replacing nodes of the factors with statements.

Advantages of ISM approach: ISM offers a variety of advantages like: i The process is systematic; the computer is programmed to consider all possible pair wise relations of system elements, either directly from the responses of the participants or by transitive inference. ii The process is efficient; depending on the context, the use of transitive inference may reduce the number of the required relational queries by from 50-80 percent. iii No knowledge of the underlying process is required of the participants; they simply must possess enough understanding of the object system to be able to respond to the series of relational queries generated by the computer. iv It guides and records the results of group deliberations on complex issues in an efficient and systematic manner. v It produces a structured model or graphical representation of the original problem situation that can be communicated more effectively to others. vi It enhances the quality of interdisciplinary and interpersonal communication within the context of the problem situation by focusing the attention of the participants on one specific question at a time. vii It encourages issue analysis by allowing participants to explore the adequacy of a proposed list of systems elements or issue statements for illuminating a specified situation. viii It serves as a learning tool by forcing participants to develop a deeper understanding of the meaning and significance of a specified element list and relation. ix It permits action or policy analysis by assisting participants in identifying particular areas for policy action which offer advantages or leverage in pursuing specified objectives.

Limitations of ISM approach: There may be many variable to a problem or issue. Increase in the number of variables to a problem or issue increases the complexity of the ISM methodology. So we can only consider limited number of variables in the development of ISM model. Other variables which are least affecting a problem or issue may not be taken in the development of ISM model. Further experts help are taken in analyzing the driving and dependence power of the variable of a problem or issue. These models are not statistically validated. Structural equation modeling (SEM), also commonly known as linear structural relationship approach has the capability of testing the validity of such hypothetical model.

Applications of ISM approach: ISM can be used at a high level of abstraction such as needed for long range planning. It can also be used at a more concrete level to process and structure details related to a problem or activity such as process design, career planning, strategic planning, engineering problems, product design, process re-engineering, complex technical problems, financial decision making, human resources, competitive analysis and electronic commerce[19, 20, 21, 22]. Application of Interpretive structural modeling (ISM) process to analyze systems and problems in various fields is well documented in literature such as:

Attri et al.[16] have applied this approach for identifying and analysing their mutual interaction of the enablers in the implementation of Total Productive Maintenance (TPM). Attri et al.[15] have applied Interpretive Structural Modelling (ISM) approach for identifying and analysing the barriers in the implementation of Total Productive Maintenance. Saxena et al.[23] have identified the key variables using direct as well as indirect interrelationships amongst the variables and presented the results of the application of ISM methodology to the case of 'Energy conservation in the Indian cement industry. Saxena et al.[24] have used this technique to identify the key factors, objectives and activities for energy conservation in the Indian cement industry. They have superimposed some fuzzy considerations to determine the hierarchy of variables and to identify the key variable of the system. Raj et al.[14] have utilised ISM approach for analysing the mutual relationships between the factors affecting the flexibility in FMS. Mandal and Deshmukh[25] have analyzed some important vendor selection criteria with the use of ISM that shows the inter-relationships of criteria and their different levels. These criteria have been categorized depending on their driving and dependence power. Sharma et al.[26] carried out ISM to develop a hierarchy of actions required to achieve the future objectives of waste management in India. Singh et al.[6] have utilized this technique for the implementation of knowledge management in engineering industries. Thakkar et al.[27] has used ISM approach for evaluating and comparing supply chain relationships, specifically when, small and medium scale enterprise (SME) is considered as focal company.

Ravi et al.[10] used this methodology to determine the key reverse logistics variables, which the top management should focus so as to improve the productivity and performance of computer hardware supply chains. Thakkar et al.[28] have used ISM approach to propose an integrated qualitative and quantitative approach to the development of a balanced scorecard (BSC) for a real life case company KVIC (Khadi and Village Industries Commission, organic food sector, India). Qureshi et al.[29] applied this approach to model the key variables of logistics outsourcing relationship between shippers and logistics service providers (LSPs) and to study their influence on productivity and competitiveness of the shipper company. Raj and Attri[7] have applied Interpretive Structural Modelling (ISM) approach for identifying and analysing the barriers in the implementation of

Total Quality Management (TQM). Faisal et al.[30] have utilized this to present an approach to effective supply chain risk mitigation by understanding the dynamics between various enablers that help to mitigate risk in a supply chain. Faisal et al.[31] applied this approach to identify various information risks that could impact a supply chain, and developed a conceptual framework to quantify and mitigate them. Agarwal et al.[9] used this methodology to identify interrelationship among the variables that have been identified for developing a framework for agility improvement of case supply chain. Singh et al.[32] have utilized this technique to identify and develop the structural relationship among different factors for successful implementation of AMTs. Jharkharia and Shankar[33] used this methodology to identify the enablers affecting the IT enablement of supply chain and to understand the mutual influences among these enablers. Bolanas et al.[34] have utilized this approach to improve decision making process among executives working in different functional areas.

MICMAC analysis: Matrice d'Impacts croises-multiplication appliqúe an classment (cross-impact matrix multiplication applied to classification) is abbreviated as MICMAC. The purpose of MICMAC analysis is to analyze the drive power and dependence power of factors. MICMAC principle is based on multiplication properties of matrices[26]. It is done to identify the key factors that drive the system in various categories. Based on their drive power and dependence power, the factors, have been classified into four categories i.e. autonomous factors, linkage factors, dependent and independent factors.

Autonomous factors: These factors have weak drive power and weak dependence power. They are relatively disconnected from the system, with which they have few links, which may be very strong.

Linkage factors: These factors have strong drive power as well as strong dependence power. These factors are unstable in the fact that any action on these factors will have an effect on others and also a feedback effect on themselves.

Dependent factors: These factors have weak drive power but strong dependence power.

Independent factors: These factors have strong drive power but weak dependence power. A factor with a very strong drive power, called the 'key factor' falls into the category of independent or linkage factors.

Conclusion

Interpretive Structural Modeling (ISM), provides an ordered, directional framework for complex problems, and gives decision makers a realistic picture of their situation and the variables involved. The ISM process involves the identification of factors, the definition of their interrelationships, and the imposition of rank order and direction to illuminate complex problems from a systems perspective. ISM process transforms unclear, poorly articulated mental models of systems into visible and well-defined models. These models help to find the key factor related to problem or issue. After identification of key factor or element, strategy may be developed for dealing issue.

ISM method is understandable to a variety of users in the interdisciplinary groups, provides a means of integrating the diverse perceptions of participating groups, is capable of handling a large number of components and relationships typical of complex systems, is heuristic in terms of assessing the adequacy of model formulation, and leads to insights about system behaviour. ISM is also easy to use and communicable to a larger audience. These features of ISM approach has resulted into wide use of this approach.

References

1. Raj T., Shankar R. and Suhaib M., An ISM approach for modeling the enablers of flexible manufacturing system: The case for India, *International Journal of Production Research*, **46(24)**, 1-30 **(2007)**
2. Farris D.R. and Sage A.P., On the use of interpretive structural modeling for worth assessment, *Computer and Electrical Engineering*, **2**, 149–174 **(1975)**
3. Sage A.P., *Interpretive structural modeling: Methodology for large scale systems*, New York, NY: McGraw-Hill **(1977)**
4. Warfield J.W., Developing interconnected matrices in structural modelling, *IEEE Transactions on Systems Men and Cybernetics*, **4(1)**, 51-81 **(1974)**
5. Ravi V. and Shankar R., Analysis of interactions among the barriers of reverse logistics. *Technological Forecasting and Social Change*, **72**, 1011-1029 **(2005)**
6. Singh M.D., Shankar R., Narain R. and Agarwal A., An interpretive structural modeling of knowledge management in engineering industries, *Journal of Advances in Management Research*, **1(1)**, 28–40 **(2003)**
7. Raj T. and Attri R., Identification and modelling of barriers in the implementation of TQM, *International Journal of Productivity and Quality Management*, **28(2)**, 153-179 **(2011)**
8. Jharkharia S. and Shankar R., IT- Enablement of supply chains: Understanding the barriers, *Journal of Enterprise Information Management*, **18(1)**, 11-27 **(2005)**
9. Agarwal A., Shankar R. and Tiwari, M.K., Modeling agility of supply chain, *Industrial Marketing Management*, **36**, 443-457 **(2006)**
10. Ravi V., Shankar R. and Tiwari M.K., Productivity improvement of a computer hardware supply chain, *International Journal of Production and Performance Measurement*, **54(4)**, 239-255 **(2005)**
11. Watson R., Interpretive Structural Modeling- A useful tool for worth assessment? *Technological Forecasting and Social Change*, **11**, 165-185 **(1978)**

12. Barve A., Kanda A. and Shankar R., Analysis of interaction among the barriers of third party logistics, *International Journal of Agile System and Management*, **2(1)**, 109-129 **(2007)**

13. Hasan M.A., Shankar R. and Sarkis J., A study of barriers to agile manufacturing, *International Journal of Agile System and Management*, **2(1)**, 1-22 **(2007)**

14. Raj T., Attri R. and Jain V., Modelling the factor affecting flexibility in FMS, *International Journal of Industrial and System Engineering*, **11(4)**, 350-374 **(2012)**

15. Attri R., Grover S., Dev N. and Kumar D., An ISM approach for modelling the enablers in the implementation of Total Productive Maintenance (TPM), *International Journal System Assurance Engineering and Management*, DOI: 10.1007/s13198-012-0088-7 **(2012)**

16. Attri R., Grover S., Dev N. and Kumar D., Analysis of barriers of Total Productive Maintenance (TPM), *International Journal System Assurance Engineering and Management*, DOI: 10.1007/s13198-012-0122-9 **(2012)**

17. Raj T. and Attri R., Quantifying barriers to implementing Total Quality Management (TQM), *European Journal of Industrial Engineering*, **4(3)**, 308-335 **(2010)**

18. Dev N., Samsher, Kachhwaha S.S. and Attri R.., GTA-based framework for evaluating the role of design parameters in cogeneration cycle power plant efficiency, *Ain Shams Engineering Journal,* http://dx.doi.org/10.1016 /j.asej.

2012.08.002 **(2012)**

19. Chidambaranathan S., Muralidharan C. and Deshmukh S.G., Analyzing the interaction of critical factors of supplier development using Interpretive Structural Modeling-an empirical study, *International Journal of Advance Manufacturing Technology*, **43**, 1081-1093 **(2009)**

20. Li W.L., Humphreys P., Chan L.Y. and Kumaraswamy M., Predicting purchasing performance: the role of supplier development programs, *Journal of Material Processing Technology,* **138(1-3)**, 243-249 **(2003)**

21. Banwet D.K. and Arora R., Enablers and inhibitors of e-commerce implementation in India-an interpretive structural modelling (ISM) approach, In: Kanda A et al (ed) *Operations management for global economy challenges and prospects*, Phoenix, New Delhi, 332-341 **(1999)**

22. Rajesh K.S., Suresh K.G. and Deshmukh S.G., Interpretive structural modelling of factors for improving competitiveness of SMEs, *International Journal of Productivity and Quality Management*, **2(4)**, 423-440 **(2007)**

23. Saxena J.P., Sushil and Vrat P., The impact of indirect relationships in classification of variables: A MICMAC analysis for energy conservation, *System Research*, **7(4)**, 245-253 **(1990)**

24. Saxena J.P., Sushil and Vrat P., Scenario building: a critical study of energy conservation in the Indian cement industry, *Technological Forecasting and Social Change*, **41(2)**, 121-146 **(1992)**

25. Mandal A. and Deshmukh S.G., Vendor selection using interpretive structural modeling (ISM), *International Journal of Operations and Production Management*, **14(6)**, 52–59 **(1994)**

26. Sharma H.D., Gupta A.D. and Sushil, The objectives of waste management in India: a future inquiry, *Technological Forecasting and Social Change*, **48**, 285–309 **(1995)**

27. Thakkar J., Kanda A., Deshmukh S.G., Evaluation of buyer-supplier relationships using an integrated mathematical approach of interpretive structural modeling (ISM) and graph theoretic approach, *Journal of Manufacturing Technology Management*, **19(1)**, 92-124 **(2008)**

28. Thakkar J., Deshmukh S.G., Gupta A.D. and Shankar R., Development of Score card: An integrated approach of ISM and ANP, *International Journal of Production and Performance Management*, **56(1)**, 25-59 **(2007)**

29. Qureshi M.N., Kumar D. and Kumar P., Modeling the logistics outsourcing relationships variables to enhance shippers productivity and competitiveness in logistics supply chain, *International Journal of Production and Performance Management*, **56(8)**, 689-714 **(2007)**

30. Faisal M.N., Banwat D.K. and Shankar R., Supply chain risk mitigation: Modeling the enablers, *Business Process Management Journal*, **12(4)**, 532-552 **(2006)**

31. Faisal M.N., Banwat D.K. and Shankar R., Information risks management in supply chain: An assessment and mitigation framework, *Journal of Enterprise Information Management*, **20(6)**, 677-699 **(2007)**

32. Singh R.K., Garg S.K., Deshmukh S.G. and Kumar M., Modeling of critical success factors for implementation of AMTs*, Journal of Modelling in Management*, **2(3)**, 232-250 **(2007)**

33. Jharkharia S. and Shankar R., IT- Enablement of supply chains: Modelling the enablers, *International Journal of Production and Performance Management*, **53(8)**, 700-712 **(2004)**

34. Bolanos R., Fontela E., Nenclares A. and Paster P., Using interpretive structural modeling in strategic decision making groups, *Management Decision*, **43(6)**, 877-895 **(2005)**