Interpretive Structural Modelling for Challenging Issues in JIT Supply Chain: Product Variety Perspective

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Abstract **— The success of JIT in Japan inspired many organizations to adopt JIT to the supply chain in order to reduce the waste and cost. These organizations have to face inherent challenging issues and complexities while implementing JIT concepts in supply chain. The manufacturer must be in position to identify challenging issues, its consequences so as to design a robust and reliable supply chain accordingly otherwise the manufacturing system may not provide the desired results. The focus of this paper is on the significant challenging issues in JIT supply chain from product variety perspective. Some challenging issues act as driver for sustainable implementation of JIT supply chain. For adoption of JIT supply chain, significant issues must be identified, analysed and discussed. In this research, study factors are the challenging issues for sustainable JIT supply chain implementation. Authors have identified ten significant issues from literature review. The main objectives are to identify and rank the challenging issues for implementation, to develop and to analysed the interaction between identified challenging issues using ISM and to prepare a framework for successful JIT supply chain implementation.**

***Keywords*— Just-in-Time (JIT), Lean, JIT Supply Chain, Challenges, Product Variety; Interpretive Structural Modelling (ISM)

1. Introduction

Adoption of JIT or lean concepts in supply chain becomes imperative for survival of any organization owing to stiff global competition in the market. The new integrated strategy called as lean supply chain. JIT is strongly integrated with supply chain management through collaboration with parts suppliers in product development, reduction of inventory and defects [2] Vendors have to play a significant role in JIT supply chain. Suppliers must acts as the seamless extension of the focal organization. In the JIT environment a supplier needs to adjust the production schedule to match the buyer's demand [33].

Product variety proliferation is a trend in many industry sectors worldwide [6], [14], [39]. Increasing product variety can be seen in the ever-increasing supply and demand of alternative products in the market place [21]. Product variety is defined as the diversity of products that a manufacturing enterprise provides to the marketplace [43], [49]. Product variety is an effective strategy to increase market share because it enables a firm to serve heterogeneous market segments and to satisfy consumer's variety seeking behavior [39], [42]. Modern customers are very demanding in terms of product variety, quality and cost. Manufacturers have to produce variety of product to meet the modern customer requirements for different market segment. Proper product mix is the key to remain competitive for the manufacturers. Mixed-model assembly lines have become popular in recent years as an integral part of JIT production systems [19]. Thousands of materials and suppliers need to be coordinated to ensure that final assembly never runs out of parts [13]. In many cases, parts used for assembly are pulled in a just-in-time manner [2]. Reliable

International Journal of Supply Chain Management
IJSCM, ISSN: 2050-7399 (Online), 2051-3771 (Print)

supply of components in JIT environment in mix model assembly line system is a challenging task. The product variety induced many challenging issues for JIT supply chain. While higher variety of products may satisfy a broader range of customers, it also introduces complexity in manufacturing [32]. The manufacturers have to walk on tight rope to establish balance in product variety and product cost.

The purposes of the paper are to explore and model the challenging issues in JIT supply chain from product variety perspective of a manufacturer using Interpretive Structural Modelling (ISM) technique. This paper is further organized as follows. The section 2 describes the research methodology; challenging issues in JIT supply chain from product variety perspective are discussed in section 3 which is followed by section 4 dedicated for Interpretive Structural Modeling (ISM). Section 5 contains MICMAC Analysis. The discussion is carried out in section 6. General conclusions with Research findings and implications and limitations are made in section 7 and direction for future work is given in section 8.

2. Research Objectives and Methodology

Published research papers have covered various domains of supply chain in JIT environment. Early papers focused on identification of JIT elements, benefits of JIT implementation, simulation, implementation strategies, impact of JIT on competitive and financial performance of the organization, the relationship between JIT and other operational practices like information systems and technology, Total Quality Management (TQM), Total Productive Maintenance (TPM), Supply Chain Management (SCM), Human Resource Management (HRM), etc. However few papers were focused on the comprehensive coverage on JIT supply chain specifically challenging issues in JIT supply chain from product variety perspective.

This work can be characterized as a theoretical concept, specifically for review of literature on challenging issues in JIT supply chain from product variety perspective of a manufacturer. First the relevant literature is reviewed.

Following criteria are used for inclusion of literature:

- Literature published from 1991 to 2013.
- Literature published on lean, JIT and ISM
- Journals stating lean and JIT in their editorial scope.
- Survey reports published on JIT by professional agencies.
- Web articles on lean and JIT
- Articles published in reputed referred scholarly journals, working papers, master theses and doctoral theses.
- Articles discussing issues and barriers in lean and JIT implementation in manufacturing sectors.
- Articles addressing issues related to the problems in lean and JIT implementation and
- Articles presenting a lean and JIT model or framework specifically in manufacturing sectors.

The literature review was augmented by use of online computerized data base such as Science Direct, Emerald, Taylor and Francis, Google Scholar, Bing etc. using primary keywords such as Just-in-Time (JIT), Lean, JIT/Lean supply chain, product variety, Interpretive Structural Modelling (ISM) and secondary key words like barriers, challenges, lack of, implementation strategy etc. The research is based on secondary data, which includes compilation of research articles. The ultimate list of articles reviewed for this paper covers articles published in reputed referred scholarly journals on supply chain management and JIT.

Fig. 1 depicts flow chart for research methodology adopted.

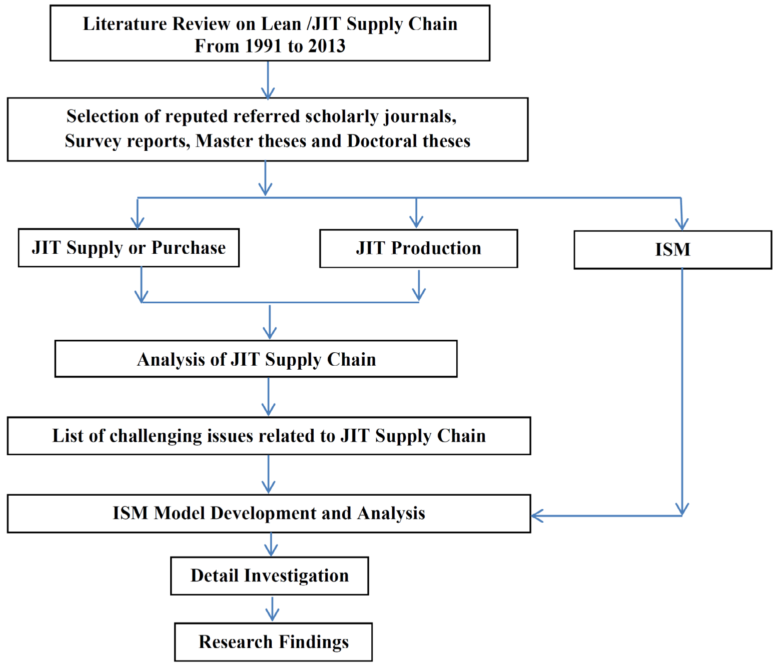


Fig. 1: Flow Chart for Research Methodology

The objectives of the paper are to identify and rank the challenging issues for implementation, to develop and to analysed the interaction between identified challenging issues using ISM and to prepare a framework for successful JIT supply chain implementation. In this study, research factors are the challenging issues in of JIT supply chain. Ten significant challenging issues have been identified after reviewing literature.

3. Challenging Issues in JIT Supply Chain

The identification of challenging issues in JIT supply chain from product variety perspective of a manufacturer is important. Fig 2 shows the challenging issues in JIT supply chain from product variety perspective of a manufacturer.

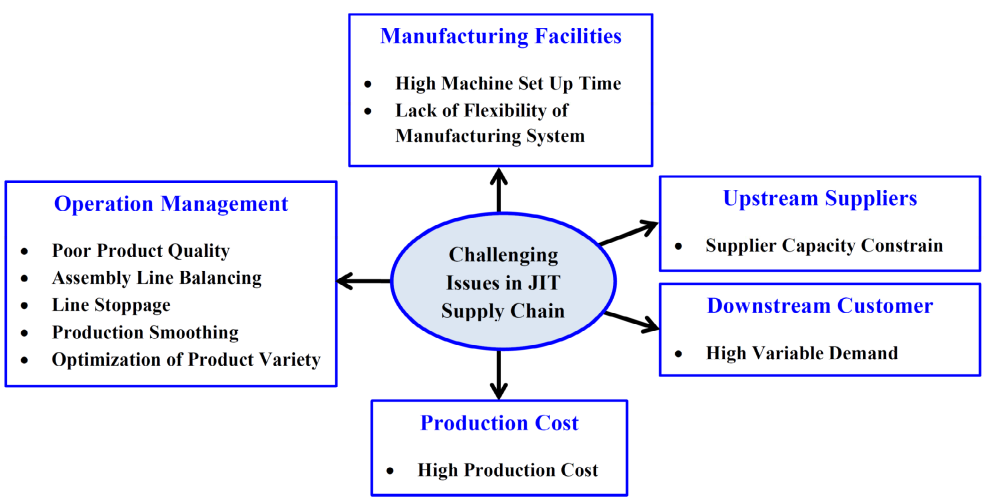


Fig 2: Challenging Issues in JIT Supply Chain - Product Variety Perspective of A Manufacturer

The description of challenging issues in JIT supply chain is as follows.

3.1 High Variance in Demand and Supply

In some industries such as the electronics industry, this increase in product variety leads to a high variance in demand [46], [48]. In JIT environment with high product variety, more material may require on shop floor in case of high variance in demand. As a result, the production cost may increase due to extra material handling, large space requirement, blocking of capital etc. Also there is possibility of variance in supply to fulfil the required demand due to extra material handling, high set up time, lack of flexibility of manufacturing system, supplier capacity constraints and other related issues.

3.2 High Machine Setup Time

Numbers of parts are to be manufacture and assembled in the same shop with increased product variety. This situation demands quick change over of tools and setup on machines otherwise the production schedule may get disturbed. According to *Mcintosh et al.* [30] it's important that changeovers are quick, so that the flexibility of respond to demand is not affected. High machine setup time also results in high production cost.

3.3 Lack of Flexibility of Manufacturing System

Manufacturing flexibility refers to ability to respond quickly to demands for different products using common resources. Lack of flexibility in manufacturing of both vendors as well as manufacture disturbs JIT supply. Lack of flexibility of manufacturing system leads to longer lead time and delayed production schedule.

3.4 Supplier Capacity Constraints

JIT advocate small but reliable supplier base. Requirement of different kinds of parts increases with high product variety. If the suppliers manufacturing facilities are not in position to supply various parts as per the demand then it may throw production schedule of focal manufacturer out of gear. Also, even under a given scheduling scenario, wide variation could exist between the ability of the various supplier plants to meet assembly requirements at the supply epochs [2].

3.5 Production Smoothing or Level scheduling or Heijunka

With the increased complexity of product structures and the level of diversification in product configurations, manufacturing operations have become increasingly more complex, rendering production smoothing for mixed-product JIT systems a considerably challenging problem [7], [8], [11], [20], [24], [34], [37] [41], [45], [46].

3.6 Assembly line balancing

Various parts and subassemblies are fitted at each work station on the main structure of product during assembly. Varying task requirements and processing times of product variants prohibit perfect synchronisation and render the assembly line balancing problem challenging [10], [47].

3.7 Line Stoppage

Frequent change in product variety increases the probability of line stoppage because of short supply of parts, material, and slow changeover etc. Line stoppage due to any reasons is a costly affair. Hence risk of line stoppage is the greatest concern for assembly line.

3.8 Poor Product Quality

Product variety demand high capabilities to recognise the requirements of different class of customer and provide different product to fulfil that requirements. Given the investment involved in developing such category expertise and the additional costs associated with offering greater variety, the firm has more to lose if buyers are subsequently disappointed by actual product quality [5].

3.9 Optimization of Product Variety

Low product variety may affect the business negatively as it makes the customer frustrate whereas high product variety may confuse the customer for proper product selection. Supporting the notion that consumers like variety, in certain product categories a reduction in assortment has been shown to lead to reduced sales [5], [9]. According to *Scavarda et al.* [38] the provision of product variety has been one of the key conflicts between manufacturing and sales departments across many industries [22], [40]. Offering product variety is one of the traditional competitive priorities in manufacturing and thus subject to operational trade-offs [12], [18], [29], [38].

It is very important to determine the critical point at which the efficient and economical degree of product variety create negative market effects and cost escalation. As a result, the central question with regards to product variety concerns the "optimum" or "appropriate" level of *variety* [25], [39].

3.10 High Production Costs

Offering a product to different markets leads to an increase in product variety as different markets require different versions of a product regarding usability, functionality or even just customers preferences, economic resources and taste [39]. Highly diversified customer needs lead to not only high product variety but also the associated cost implications [49]. *Scavarda et al.,* [39] stated that a proliferation of products results in deterioration in manufacturing/logistics performance [23], what can result in higher forecast errors, excessive inventory for some products, shortages for others and higher costs [26]. Different kinds of inventories are required in multimodel assembly lines. Production cost set to increase due to additional material handling and logistics, extra space requirements, frequent set ups etc.

4. Interpretive Structural Modeling (ISM)

4.1 Introduction to ISM

ISM is a well-proven strategy for analyzing the synergic influences of various attributes to the overall system under study [35]. 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 [3]. The ISM process transforms unclear, poorly articulated mental models of systems into visible, well-defined models useful for many purposes [1], [31]. Interpretive structural modeling (ISM) helps in identifying the inter-relationships among variables. It is a suitable modeling technique for analyzing the influence of one variable on other variables [27].

ISM has been used by researchers for understanding direct and indirect relationships among various variables in different industries. *Faisal et al.* [16] used ISM to analyse the enablers for supply chain agility. *Barve* [4] studied the effect of agility in supply chains on customer satisfaction using interpretive structural modelling. *Madaan et al.* [27] provided a multi-objective decision model using interpretive structural modelling (ISM) based approach to enrich and initiate the green supply chain activities in an organization.

4.2 Development of Model using ISM

A stepwise procedure is to be adopted to develop a model or frame work using ISM. *Ravi and Shankar* [36] described the various steps involved in the ISM methodology as follows:

Step 1: Variables affecting the system under consideration are listed, which can be objectives, actions, and individuals etc.

Step 2: From the variables identified in step 1, a contextual relationship is established among variables with respect to which pairs of variables would be examined.

Step 3: A Structural Self-Interaction Matrix (SSIM) is developed for variables, which indicates pair wise relationships among variables of the system under consideration.

Step 4: Reachability matrix is developed from the SSIM and the matrix is checked for transitivity. The transitivity of the contextual relation is a basic assumption made in ISM. It states that if a variable A is related to B and B is related to C, then A is necessarily related to C.

Step 5: The reachability matrix obtained in Step 4 is partitioned into different levels.

Step 6: Based on the relationships given above in the reachability matrix, a directed graph is drawn and the transitive links are removed.

Step 7: The resultant digraph is converted into an ISM, by replacing variable nodes with statements.

Step 8: The ISM model developed in Step 7 is reviewed to check for conceptual inconsistency and necessary modifications are made.

4.3 Interpretive Structural Model (ISM) Development

The interrelationships among different challenging issues in JIT supply chain implementation have been achieved through these steps mentioned above.

4.3.1 Structural Self-Interaction Matrix (SSIM)

Ten challenging issues in JIT supply chain implementation are identified through literature review. The next step is to analyse the interrelationship between these challenging issues using ISM. ISM methodology proposes the use of the expert opinions based on various management techniques such as brainstorming and nominal group discussion technique in developing the contextual relationship between challenging issues. These experts from the industry and academia were well conversant with JIT supply chain.

'Leads to' or 'influences' type of contextual relationship is chosen for analyzing the challenging issues. This means that a particular challenging issues 'leads to' or ;influences' another issue. On the basis of this, contextual relationship between the challenging issues is developed.

Following four symbols were used to denote the direction of relationship between the issues in JIT supply chain (*i* and *j*):

V: challenging issue *i* influences challenging issue *j*

A: challenging issue *i* influenced by challenging issue *j*

X: challenging issue *i* and *j* influence each other

O: challenging issue *i* and *j* do not influence each other since they are unrelated

Consultation and discussions with the five JIT supply chain experts, helped in identifying the relationships between the identified challenging issues. On the basis of contextual relationship between challenging issues, the SSIM has been developed. Final SSIM is presented in Table 1.

Table 1: Structural Self Interaction Matrix

SN	Challenging Issues	10	9	8	7	6	5	4	3	2	1
1	High Variance in Demand and Supply	V	V	O	V	V	V	A	A	A	
2	High Machine Setup Time	V	V	O	V	V	V	O	V		
3	Lack of Flexibility of Manufacturing System	V	V	O	V	V	V	A			
4	Supplier Capacity Constraints	O	V	O	V	O	O				
5	Level scheduling	V	V	O	V	X					
6	Assembly line balancing	V	V	O	V						
7	Line Stoppage	V	O	O							
8	Poor Product Quality	V	O								
9	Optimization Of Product Variety	V									
10	High Production Costs										

4.3.2 Development of the initial and final reachability matrix:

The next step is to develop the initial and final reachability matrix from the SSIM.

(i) *Initial reachability matrix*

Obtain the initial reachability matrix from the SSIM format by transforming the information of each cell of SSIM into binary digits (i.e., 1s or 0s). This transformation has been done by substituting V, A, X, O by 1 and 0 as per the following rules. Rules for transformation are given in Table 2.

Table 2 : Rules for transformation

If the (*i, j*) entry in the SSIM is	Entry in the initial reachability matrix	
	(*i, j*)	**(*j, i*)**
V	1	0
A	0	1
X	1	1
O	0	0

Following these rules, initial reachability matrix is prepared as shown in Table 3.

Table 3: Initial Reachability Matrix

SN	Challenging Issues	10	9	8	7	6	5	4	3	2	1
1	High Variance in Demand and Supply	1	1	0	1	1	1	0	0	0	1
2	High Machine Setup Time	1	1	0	1	1	1	0	1	1	1
3	Lack of Flexibility of Manufacturing System	1	1	0	1	1	1	0	1	0	1
4	Supplier Capacity Constraints	0	1	0	1	0	0	1	1	0	1
5	Level scheduling	1	1	0	1	1	1	0	0	0	0
6	Assembly line balancing	1	1	0	1	1	1	0	0	0	0
7	Line Stoppage	1	0	0	1	0	0	0	0	0	0
8	Poor Product Quality	1	0	1	0	0	0	0	0	0	0
9	Optimization of Product Variety	1	1	0	0	0	0	0	0	0	0
10	High Production Costs	1	0	0	0	0	0	0	0	0	0

(ii) *Final reachability matrix*

To get Final reachability matrix, the concept of transitivity is introduced, and some of the cells of the initial reachability matrix are filled in by inference. If a variable *'i'* is related to *'j'* and *'j'* is related to *'k'*, then transitivity implies that variable *'i'* is necessarily related to *'k'*. The final reachability matrix is developed after incorporating the transitivity concept in Table 3 and is presented in Table 4 wherein entries marked † show the transitivity.

Table 4: Final Reachability Matrix

S.N.	Challenging Issues	10	9	8	7	6	5	4	3	2	1	Driver Powe
1	High Variance in Demand & Supply	1	1	0	1	1	1	0	0	0	1	6
2	High Machine Setup Time	1	1	0	1	1	1	0	1	1	1	8
3	Lack of Flexibility of Manufacturing System	1	1	0	1	1	1	0	1	0	1	7
4	Supplier Capacity Constraints	†1	1	0	1	0	0	1	1	0	1	6
5	Level scheduling	1	1	0	1	1	1	0	0	0	0	5
6	Assembly line balancing	1	1	0	1	1	1	0	0	0	0	5
7	Line Stoppage	1	0	0	1	0	0	0	0	0	0	2
8	Poor Product Quality	1	0	1	0	0	0	0	0	0	0	2
9	Optimization Of Product Variety	1	1	0	0	0	0	0	0	0	0	2
10	High Production Costs	1	0	0	0	0	0	0	0	0	0	1
	Dependence	10	7	1	7	5	5	1	3	1	4	

4.3.3 Level partitioning the final reachability matrix:

After creating the final reachability matrix, obtain the structural model. *Warfield* [44] has presented a series of partitions, which are induced by the reachability matrix on the set and subset of different variables. From these partitions one can identify many properties of the structural model [17].

The reachability set and antecedent set for issues are determined from the final reachability matrix. The reachability set for a particular issue consists of the issue itself and the other issues, which it influences. Whereas the antecedent set consists of the issue itself and the other issues which may influence it. Subsequently, the intersection of the reachability and antecedent sets is obtained for all the issues and levels of different issues are determined. The issues, for which the reachability sets and the intersection sets are identical, assigned the top level in the ISM hierarchy. The top-level issues are those that will not lead the other issues above their own level in the hierarchy. Once the top-level issue is identified, it is eliminated from further hierarchical analysis and other top-level issues of the remaining sub-group are identified. This iteration is repeated till the levels of each issue are determined (Tables 5 to 10). Level partition of these issues is accomplished in six iterations.

Table 5 : Level Partition – Iteration 1

Issue No.	Reachability Set	Antecedent Set	Intersection Set	Level
1	1, 5,6,7,9,10	1, 2, 3, 4	1	
2	1, 2, 3, 5,6,7, 9,10	2	2	
3	1, 3, 5,6,7, 9,10	2, 3, 4	3	
4	1, 3, 4, 7, 9, 10	4	4	
5	5, 6, 7, 9, 10	1, 2, 3, 5, 6	5, 6	
6	5, 6, 7, 9, 10	1, 2, 3, 5, 6	5, 6	
7	7, 10	1, 2, 3, 4, 5, 6, 7	7	
8	8, 10	8	8	
9	9, 10	1, 2, 3, 4, 5, 6, 9	9	
10	10	1, 2, 3, 4, 5, 6, 7, 8, 9, 10	10	I

Table 6 : Level Partition – Iteration 2

Issue No.	Reachability Set	Antecedent Set	Intersection Set	Level
1	1, 5,6,7,9	1, 2, 3, 4	1	
2	1, 2, 3, 5,6,7, 9	2	2	
3	1, 3, 5,6,7, 9	2, 3, 4	3	
4	1, 3, 4, 7, 9	4	4	
5	5, 6, 7, 9	1, 2, 3, 5, 6	5, 6	
6	5, 6, 7, 9	1, 2, 3, 5, 6	5, 6	
7	7	1, 2, 3, 4, 5, 6, 7	7	II
8	8	8	8	II
9	9	1, 2, 3, 4, 5, 6, 9	9	II

Table 7 : Level Partition – Iteration 3

Issue No.	Reachability Set	Antecedent Set	Intersection Set	Level
1	1, 5,6	1, 2, 3, 4	1	
2	1, 2, 3, 5,6	2	2	
3	1, 3, 5,6	2, 3, 4	3	
4	1, 3, 4	4	4	
5	5, 6	1, 2, 3, 5, 6	5, 6	III
6	5, 6	1, 2, 3, 5, 6	5, 6	III

Table 8 : Level Partition – Iteration 4

Issue No.	Reachability Set	Antecedent Set	Intersection Set	Level
1	1	1, 2, 3, 4	1	IV
2	1, 2, 3	2	2	
3	1, 3	2, 3, 4	3	
4	1, 3, 4	4	4	

Table 9 : Level Partition – Iteration 5

Issue No.	Reachability Set	Antecedent Set	Intersection Set	Level
2	2, 3	2	2	
3	3	2, 3, 4	3	VI
4	3, 4	4	4	

Table 10 : Level Partition – Iteration 6

Issue No.	Reachability Set	Antecedent Set	Intersection Set	Level
2	2	2	2	VI
4	4	4	4	VI

Final list of Level Partitions is given in Table 11. The identified levels aids in building the final model of ISM. First level issue is positioned at the top of model and so on.

Table 11 Final list of Level Partitions

Level	Issue No.	Issue
I	10	High Production Costs
II	7	Line Stoppage
	8	Poor Product Quality
	9	Optimization of Product Variety
III	5	Level scheduling
	6	Assembly line balancing
IV	1	High Variance in Demand and Supply
V	3	Lack of Flexibility of Manufacturing System
VI	2	High Machine Setup Time
	4	Supplier Capacity Constraints

4.3.4 Building the ISM-based model

The model developed with the identified challenging issues in JIT supply chain is shown in Figure 3. It is clear from the ISM model that the most important issues that enables successful implementation of JIT supply chain are high machine setup time and supplier capacity constraints, which form the base of ISM hierarchy whereas high production cost which is dependent on other issues has been appeared on top of the hierarchy.

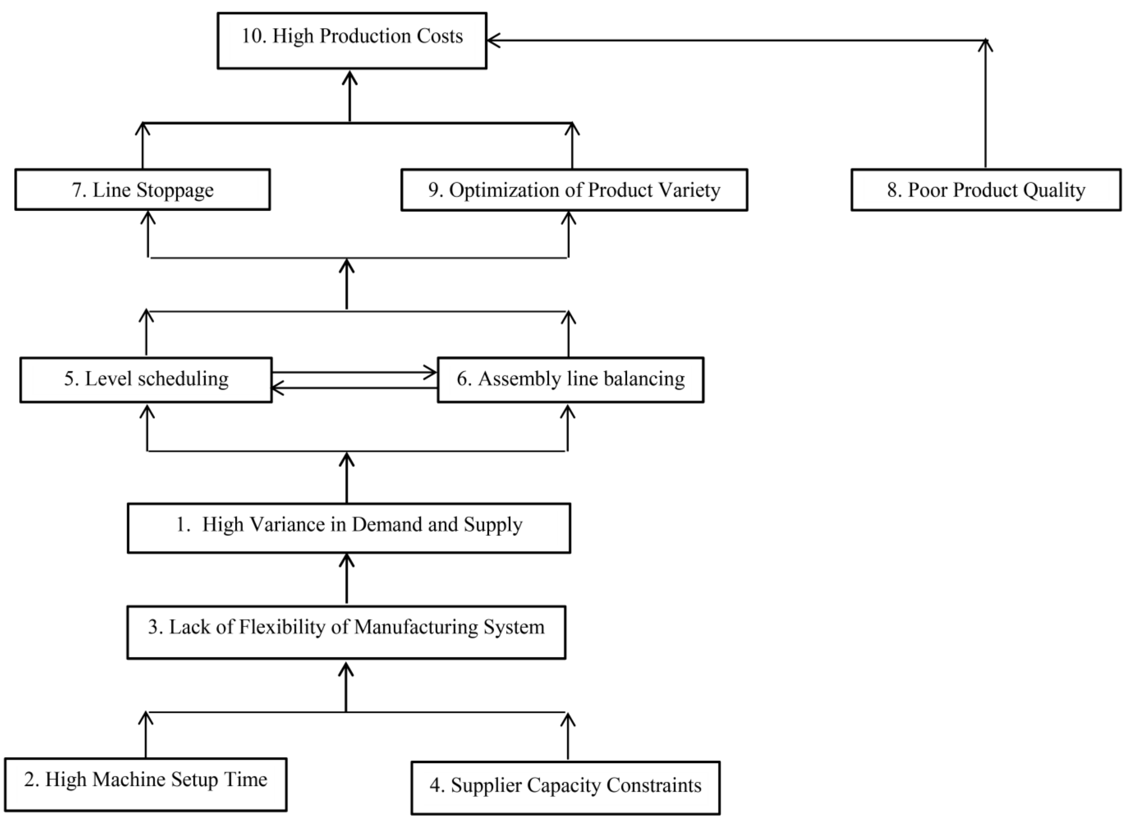


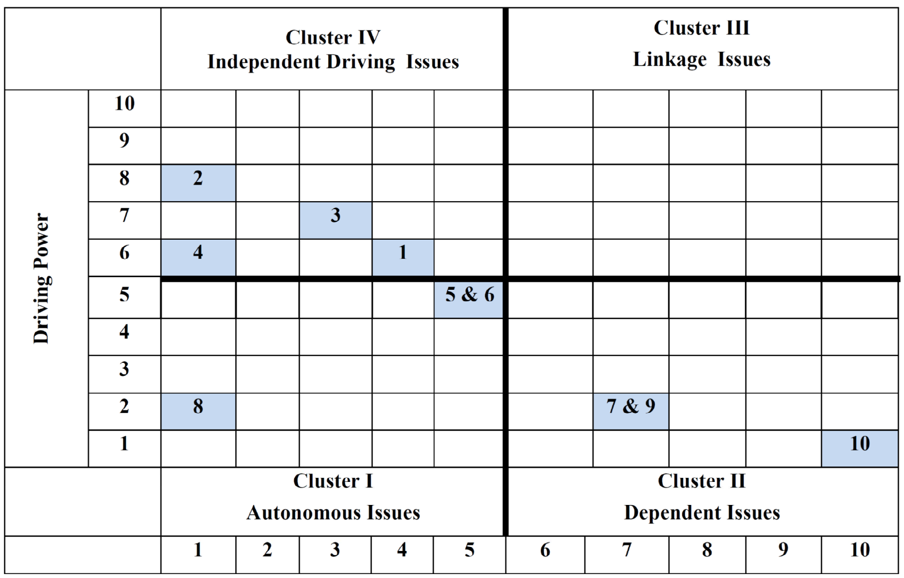
Fig. 3: ISM Model

5. 'MICMAC' Analysis

The objective of the MICMAC analysis is to analyze the driving power and the dependence of the variables [15], [28]. The dependence and the driving power of each of these challenging issues are given in Table 4. In this table, an entry of '1' along the rows and columns indicates the driving power and the dependence, respectively. Subsequently, the driving power -dependence diagram is constructed as shown in Figure 4.

In this analysis, the challenging issues in JIT supply chain described earlier are classified into four clusters (Fig. 4): (i) Autonomous issues, (ii) Dependent issues, (iii) Linkage issues and (iv) Independent issues.

Independent issues cluster consists of high machine set up, supplier capacity constraints, lack of flexibility of manufacturing system, high variance in demand. These issues are the key drivers for JIT supply chain implementation. Management has to pay maximum attention to these issues to get quick and sustainable results. Poor product quality, level scheduling and assembly line balancing falls in autonomous cluster which has weak driving power and weak dependence (refer to Fig. 4). These issues are relatively disconnected from the whole system and have very few links, which may be strong. Table 12 provides more details about clusters and its characteristics.



Dependence

Fig. 4 Driving Power - Dependence Diagram

Table 12 : Clusters and its Characteristics

Cluster No.	Clusters	Characteristics	Driving Power	Depen-dence	Challenging Issues
I	Autonomous Issues	These issues are relatively disconnected from the system, with which they have only few links, which may not be strong.	Weak	Weak	• Poor Product Quality • Level scheduling • Assembly line balancing
II	Dependent Issues	These issues are the automatic followers of other issues.	weak	Strong	• High production costs • Line stoppage • Optimization of product variety
III	Linkage Issues	These issues are unstable, in the sense that any action on these issues will have an effect on others and also a feedback on	Strong (key variable)	Strong	--

		themselves.		
IV	Independent Issues	These issues are the key drivers for implementation. Management has to pay maximum attention to these issues to get quick results.	Strong weak (key variable)	• High machine set up • Supplier capacity constraints • Lack of flexibility of manufacturing system • High variance in demand

6. Discussion

ISM model (Fig. 3) provides a direction for successful JIT supply chain implementation in the organization in a phasewise manner. It shows the sequential approach for sustainable JIT supply chain implementation. In this sequence the order of perticular issue is very important. If JIT supply chain implementation is not in the apt sequence then there is higk risk of its failure.

ISM-based model for challenging issues in JIT supply chain (Fig.3) recommends the priority order of implementation of in JIT supply chain as follows:

1. (a) Supplier capacity constraints
   (b) High machine setup time
2. Lack of flexibility of manufacturing system
3. High variance in demand
4. (a) Assembly line balancing
   (b) Level scheduling
5. (a) Line stoppage
   (b) Optimization of product variety
   (c) Poor product quality
6. High production costs

It is obvious from ISM model and MMICMAC analysis that supplier capacity constraints and high machine setup time are the most independent issues. The manufacturer does not have control on the vendor's production capacity (external factor). Hence the manufacturer has to take decisions about mutual beneficial partnership with suppliers, vendor development programs etc. since JIT advocates small reliable supplier base. High machine set up time (internal factor) can be reduced with the help of single minute exchange of dies (SMED) techniques. Flexibility of manufacturing system may be cramp due to supplier capacity constraints and high machine setup time manufacturing system as it offers slow response to customer requirements. The manufacturing system may not in position to meet the demand of internal/external customers lead to high variance in demand and supply. Assembly line balancing and level scheduling are related to each other. Stabilization of the manufacturing system needs proper assembly line balancing and level scheduling of variety of product to cope up with high variance in demand and to avoid the stoppage of assembly lines otherwise production cost becomes high. Thus optimization of product variety becomes essential.

The most interesting part of the model is the presence of autonomous issue i.e. poor product quality. This issue is relatively isolated or disconnected from the system under study. It has no backward links. It does not have single connecting challenging issues of JIT supply chain under consideration. It has only one forward links which results in to high production cost.

From the above discussion it is clear that ISM model along with MICMAC analysis offers an excellent framework for successful implementation of JIT supply chain.

7. Conclusions

7.1 Research findings and implications

This paper makes develops a model to analysed ten challenging issues in JIT supply chain. Although, ample literature is available on JIT supply chain and various issues related to it. The relationship between challenging issues has not been modelled for manufacturing organizations. The present model will help managers and supply chain practitioners to understand the relationship in detail. This research offer significant contribution in this regards.

In this research, challenging issues in JIT supply chain of manufacturing organizations are modelled in terms of their driving power and dependence. Strong driving power (with weak dependence) issues should be dealt with strategic actions as they influence other issues.

Production cost reduction without compromising on quality can be attained by improving the driving issues continually. The purposes of present research include identification and ranking the challenging issues in JIT supply chain and their influence on cost reduction. An ISM model showing interaction would offer a great help to managers and supply chain practitioners. Contextual relationship between the issues developed using brainstorming. An overall implementation structure was built for the JIT supply chain system using ISM. The overall effort put in the present research has ensued in identification of significant challenging issues in JIT supply chain for sustainable implementation in manufacturing organizations and in development of interrelationships to gain managerial insights into the priority of these issues.

7.2 Limitations and Suggestions for future research

The present study is primarily focused on challenging issues in JIT supply chain in manufacturing sector. The issues in other sectors may slightly differ from manufacturing sector. The issues may vary based on country, geographic location within the country and work culture of the organization. The ISM model is highly dependent on the experience and judgment of the expert team. The model developed using ISM needs to be validated.

8. Future Work

Once the challenging issues in JIT supply chain are identified, a number of research propositions may be proposed that would be appropriate for further study and research relating to the modelling the challenging issues using various modelling techniques like AHP, ANP etc. Implementation strategy can be developed for successful and sustainable implementation of JIT supply chain using tools like Quality Function Deployment (QFD), Failure Mode and Effect Analysis (FMEA), Balance Score Card and Hoshin Kanari policy deployment etc. Research work in this area may act as a roadmap for successful JIT supply chain implementation. It would be a light house to supply chain practitioners and researchers.

Acknowledgements

The authors wish to thank all the experts who help us in developing the structural self-interaction matrix, which is the foundation of this research work and verifying the logical consistencies of the ISM model. The authors wish to thank the anonymous referees for their valuable feedback and constructive comments which helped to improve the structure and quality of this paper. The authors are also express sincere thanks to the editor and his team for continuous guidance and support for this work.

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