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INTERPRETIVE STRUCTURAL MODELLING OF DELIVERY IMPROVEMENT PARAMETERS IN MAKE TO ORDER ENVIRONMENTS

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ABSTRACT

In this leading global manufacturing hub, the demand fluctuations in domestic and international markets are creating delivery issues, neck- to- neck competition, and loss of quality output and customer. Delayed supply in make-to-order environments would negatively affect the reputation and business prospects of the associated firm. The issues can be resolved through planning processes. The current stand- alone planning systems are not that much efficient and fail to provide ultimate planning functionality. In total six affecting parameters of delivery improvement were found, where the emphasis of the study was placed. This paper contains a thorough study that will identify the interrelationships and their impact on delivery management as well as understanding them by examining them one by one, as they have been identified by the existing literature reviews and previous studies. Subsequently, their relative importance will be analysed by using Interpretive Structural Modelling (ISM) using information gathered from expert opinions.

Keywords: Delivery issues, Demand fluctuations, Interpretive Structural Modelling (ISM), Make to Order environments

1.1 Introduction

When an overall profit-loss chart, for any given manufacturing firm is drawn for the given set of products they are manufacturing, is analysed, then the need of channelizing various input measures is highly recommended. One of the chief problems faced by any manufacturing hub consists of complex on-time delivery issues. The complexity of the issues is due to the presence of a large number of affecting parameters and their mutual interrelationships. Hence, it creates the necessity of the development of an effective methodology, which aids in identifying a proper structure within the system. Interpretive Structure Modelling(ISM) plays an important role here. It may be defined as a process, which is aimed at assisting the human being for better understanding what he/she believes and to recognise clearly, what he/she does not know. Organisational is the most essential function. The information added (by the process) is zero. The value added is structural (Rajesh Attri et al, 2013). It helps in problem solving of the inter-relationship and brings into consideration a system of directly and indirectly related elements, which narrates the complex organizational issues (Warfield, 1976, Warfield, 1982, Sage. and Rouse1999). In the present scenario, manufacturing environment is considered as a highly competitive, dynamic, and volatile hub.

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1.2 Significance of make to order environment

Make to order is a production approach, where products are not building until the order confirmation is done for the same. It starts only after a customer order is received. No stocks are maintained prior to order confirmation.

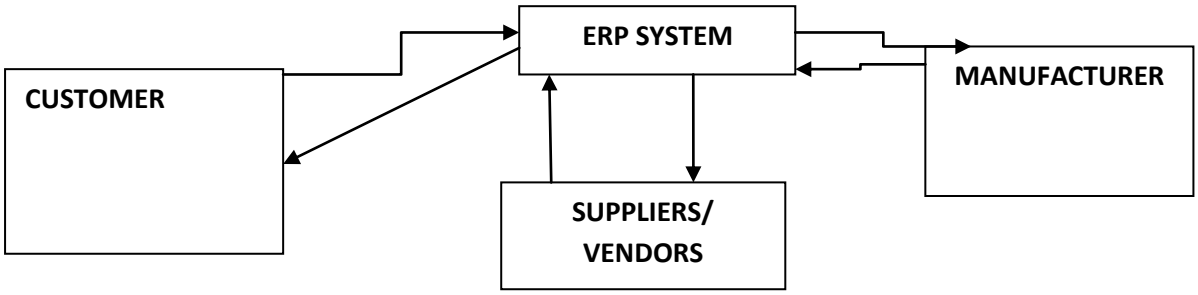


Fig. 1 (a) Make to Order Environment

1.3 Factors causing major deliveryissues

The major delivery issues arise due to the following factors:

1. Lead Time:In this rapidly growing world, it is becoming more and more critical for the manufacturing companies to reduce the lead-time to market. Lesser lead-time definitely gives a competitive edge to any company. This calls for a well-implemented supply chain and better management of the resources. It is described by the latency between the initiation and execution process. It includes procurement time, processing time, and assembly time. It is the difference between the time when an item is created and the time when the item enters its final stage.

[Lead time = End date – Create date]

2. Production Rate:In manufacturing, the number of goods that can be produced during a given period defines the production rate of a firm. Alternatively, the amount of time it takes to produce one unit of any type of good. In other words, it is said to be the rate at which workers are expected to finish a given task, assigned to them.

Production rate (hourly) = no. of units produced during a day/ no. of production hours in a day

3. Demand:With the increase in number of units required for sales, the manufacturing companies need a channelized approach towards the utilization of their resources. Demand is the quantity of a commodity or a service that people buy at a certain price. The machines have always been the hub for optimum utilization and high productivity and they continue to be so. The challenges faced by various manufacturing industries across the globe vary across the various lines of business they are into, and on the regional parameters like climate, resources, finance,etc. The preferences and choices of order and order quantities, which underlies the actual demand, can be represented as various functions, such as, cost, benefit, odds, etc.

4. Administrative & Logical Bottlenecks:A bottleneck is kind of obstacle and considered as one process in a manufacturing supply chain, such that its limited capacity reduces the capacity and efficiency of the whole chain. Bottlenecks lead to stalls in production, supply overstock, delivery pressure from customers and low employee morale. Both short and long-term bottlenecks are there. Short-term bottlenecks are mostly temporary and are not normally a critical problem. Long-term bottlenecks may occur all the time and can significantly slow down the overall production. A long-term bottleneck can be considered when a machine is not efficient enough or there is a machine breakdown and as a result has a long queue of operations left.

5. Outsourcing: It is a practice followed by various companies, all over the world, to reduce overall costs by transferring small or all portions of work to outside suppliers rather than completing the whole project internally due to several company constraints, such as time constraints, resources constraints, delivery constraints, etc. Outsourcing is an effective cost-saving and timesaving strategy when used properly, thus leads to on- time deliveries.

6. Transportation Activities:The transportation activities determine the efficiency of moving goods or items. The progress in transportation techniques improves the moving load, delivery speed, service quality, operation costs, the usage of facilities and energy conservation. Transportation takes a crucial part in the manipulation of logistic chains. Production processes involve huge numbers of inputs and outputs. It is usually required to aggregate these in order to keep the analysis under control. In case of labour and types of transportation, the measuring inputs and outputs are as follows:

- material inputs: volume/mass
- human inputs: labour and users (time)
- service inputs: navigation, terminal operations
- capital inputs: physical units, monetary units (stocks & flows)
- design inputs: dimensions, weight, power
- transportation: cargo trips, vehicle trips, vehicle miles, capacity miles, miles

II LITERATURE REVIEW

S.No.	On-Time Delivery Affecting Variables	Researchers
1.	Effective scheduling to reduce waiting time	Hayes & Wheelwright (1984); Skinner (1974); Poppendieck (2002); Heizer & Render (2006); Womack et al. (1990)

2.	Part standardization to reduce complexity and excessive processing	Kasul & Motwani (1997); Liker (2004)
3.	Efficient use of newer more efficient technology	Edwards (1996)
4.	Collaborative decision making	Kasul & Motwani (1997); Ahuja (1996)
5.	Appropriate quality of manufacturing facilities	EPA (2003)
6.	Improved quality of raw material	Nakamura, Sakakibara & Schroeder (1998); Forza (1996); Shah & Ward (2003); Taj (2008)
7.	Optimization of transportation and material handling	LEI (2003); Karlsson & Åhlström (1996); Womack et al. (1990)

III RESEARCH METHODOLOGY

The main objectives of this paper are:

a) To identify and rank the delivery parameters for implementation of on time delivery practices in a make to order environment
b) To develop and analyze the interaction between identified affecting delivery parameters using ISM
c) To prepare a framework for on time delivery system implementation
In this research, study factors are the delivery affecting parameters in a make to order environment. Author has identified six significant factors from various literature review, other existing studies, and opinion of the experts. This work can be characterized as first theoretical concept, specifically for review of literature on delivery improvement and reduction in unwanted delays. The approach of the research is mainly exploratory in nature, which constitutes a secondary source for the progress. First, the relevant literature is reviewed and marked. The author focused on literature from 2000 to 2016. The Literature Review chiefly includes implementation of ISM technique in manufacturing environments and other service sectors as well. The literature survey was supplemented by use of online database such as Taylor and Francis Science Direct, Google Scholar, Bing etc. using primary keywords such as delivery, on time delivery and make to order, ISM technique, etc. and secondary key words like improvement, modelling, framework, etc.

Majorly, the research is based on the collected secondary data, which includes compilation of various research articles and different industrial survey reports, etc., after scanning the reference sections of the selected papers. The endmost list of articles reviewed for this research paper covers articles, which are published in reputed referred scholarly journals on delivery improvement and ISM.

3.1 Identification of factors

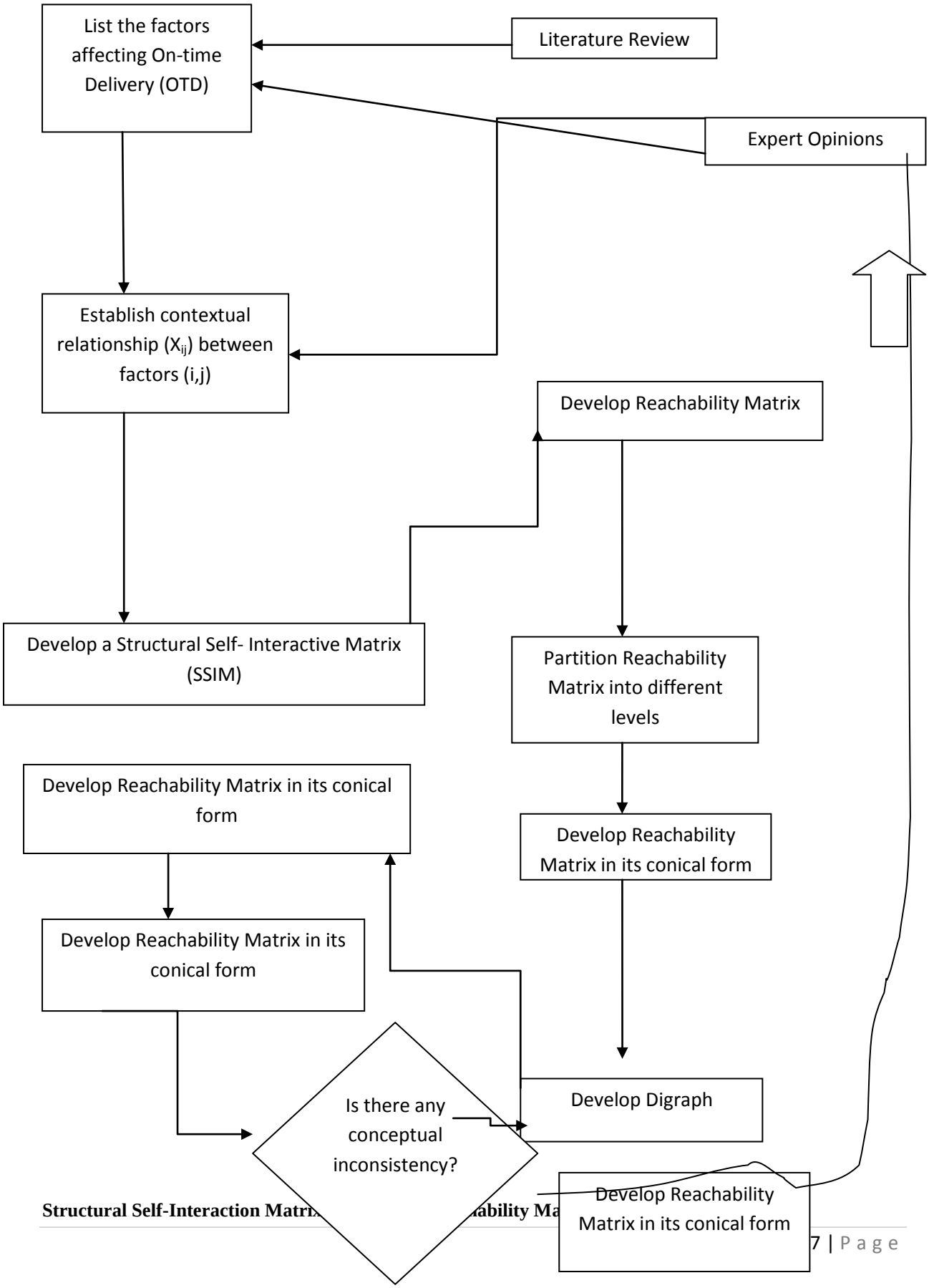
S.No.	Parameters Affecting Delivery Performance
1	Outsourcing
2	Production rate
3	Lead time
4	Demand
5	Administrative & logistical bottlenecks
6	Transportation activities

ISM may be used for identifying and summarizing relationships among specific variables, which define a problem or an issue (Warfield, 1974; Sage, 1977). It provides us a means by which order may be imposed on the complexity of such variables (Mandal & Deshmukh, 1994; Jharkharia & Shankar, 2005; Luthra, Kumar, Kumar & Haleem, 2011). The ISM is interpretive as the judgment of the selected group for the study decides whether and how the factors are interrelated.This section deals with discussion of ISM methodology. A tabulated data comprising of different steps for ISM methodology is as follows:

Table 1: Steps involved in Interpretive Structural Modelling

STEP 1	Variables affecting the system are marked and listed; in this research, factors affecting delivery performance in MTO environment have been identified as variables.
STEP 2	From the variables identified in step 1, contextual relationships among variables are examined.[1]
STEP 3	A Structural Self-Interaction Matrix (SSIM) is developed for variables, which indicates pair wise relationship among variables of the system under study.[1]
STEP 4	A Reachability Matrix is developed from the SSIM and the final matrix is checked for transitivity. The transitivity of the contextual relationships is a basic assumption made in ISM. It states that if a variable A is related to variable B and variable B is related to the variable C, then variable A necessarily is related to variable C. [1]
STEP 5	The reachability matrix obtained in Step 4 is sectioned into different levels.[2]
STEP 6	Based on the contextual relationships in the reachability matrix, a digraph is drawn and the transitivity links are removed.[3]
STEP 7	The resultant digraph is converted into an Interpretive Structural Model by replacing variable nodes with statements.[4]

Fig.1: Flow Diagram for ISM Preparation


List the factors affecting On-time Delivery (OTD)
Literature Review
Expert Opinions
Establish contextual relationship (X_{ij}) between factors (i,j)
Develop Reachability Matrix
Develop a Structural Self- Interactive Matrix (SSIM)
Partition Reachability Matrix into different levels
Develop Reachability Matrix in its conical form
Develop Reachability Matrix in its conical form
Develop Reachability Matrix in its conical form
Is there any conceptual inconsistency?
Develop Digraph
Develop Reachability Matrix in its conical form

In the present research, for identifying the contextual relationship among the variables for the delivery improvement, many experts from academia and industry, were consulted. These experts from the academia and from theindustry were well conversant with manufacturing systemimplementation, production cycles, and delivery variables in make to order environments.Based on contextual relationship among the variables, SSIM hasbeen developed. Four symbols have been used to denote the direction of the relationshipbetween the variables (i and j)[2]:

Table 2: Symbols used to denote the interrelationships between the variables

V	Variable i will help to achieve variable j;
A	Variable j will help to achieve variable i;
X	Variable i and j will help to achieve each other; and
O	Variable i and j are unrelated.

Table 3: Structural Self-Interaction Matrix

S.N.	Delivery affecting parameters	6	5	4	3	2	1
1	Outsourcing	V	V	V	V	V	-
2	Production rate	A	A	A	A	-	
3	Lead time	A	A	V	-		
4	Demand	O	O	-			
5	Administrative & logistical bottlenecks	A	-				
6	Transportation activities	-					

Table 4: 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

Table 5: Final Reachability Matrix

Variables	1	2	3	4	5	6	Driver power
1	1	1	1	1	1	1	6
2	0	1	0	0	0	0	1
3	0	1	1	1	0	0	3
4	0	1	0	1	0	0	2
5	0	1	1	0	1	0	3
6	0	1	1	0	1	1	4
Dependence	1	6	4	3	3	2	

3.2 Level Partitions

Table 6: Partitioning of Variables-Iteration 1

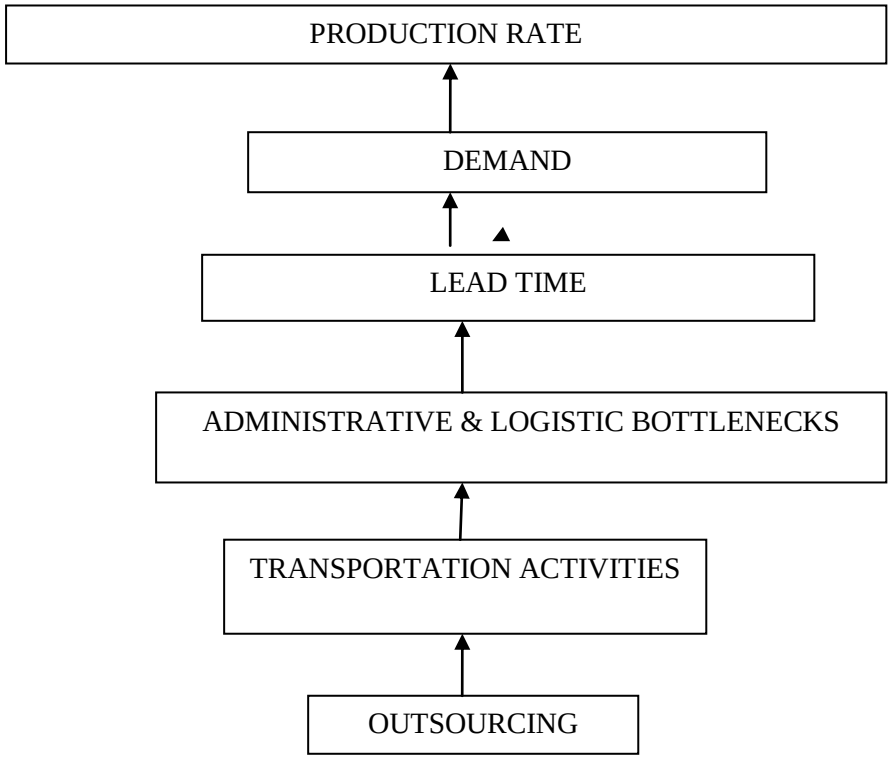
Variables	Reachability Set	Antecedent Set	Intersection Set	Level
1	1,2,3,4,5,6	1	1	
2	2	1,2,3,4,5,6	2	I
3	2,3,4	1,3,5,6	3	
4	2,4	1,3,4	4	
5	2,3,5	1,5,6	5	
6	2,3,5,6	1,6	6	

The reachability set and antecedent set (Warfield, 1974) for each parameter have been found out from the final reachability matrix. Subsequently, the intersection set of these sets have been derived for all variables. The variable for which the reachability set and the intersection set are the same has been given the topmost level in the ISM hierarchy.

Table 7: Partitioning of Variables- Final Matrix

Variables	Reachability Set	Antecedent Set	Intersection Set	Level
1	1,2,3,4,5,6	1	1	VI
2	2	1,2,3,4,5,6	2	I
3	2,3,4	1,3,5,6	3	III
4	2,4	1,3,4	4	II
5	2,3,5	1,5,6	5	IV
6	2,3,5,6	1,6	6	V

3.3 Formation of ISM-based Model



IV LIMITATIONS OF THE STUDY

This research paper is based on the Academic experts' opinions of ten persons with a focus on Indian manufacturing industries. The limitation of this study is that it is not based on a wide range of opinions of persons representing the global manufacturing industries. The ISM model, thus obtained, has not been validated through any of the statistical techniques.

V CONCLUSIONS

Waste minimization and improving efficiency have been identified as key objectives of lean manufacturing system implementation. The intensive Literature review and vigorous discussions with area experts have helped to sort the variables relevant to variables affecting on time deliveries in Make-to-Order environments based upon their order of importance. Production Rate has been ranked the most critical factor andoutsourcing has been identified as the most critical bottom level factor in ISM hierarchy.

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