Evaluation of Drivers and Barriers for Agent Technology in Manufacturing System

MASTER OF TECHNOLOGY
DISSERTATION REPORT

BY

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(2015PIE5196)

DEPARTMENT OF MECHANICAL ENGINEERING
MALAVIYA NATIONAL INSTITUTE OF TECHNOLOGY JAIPUR

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Evaluation of Drivers and Barriers for Agent Technology in Manufacturing System

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BY

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UNDER THE GUIDANCE OF
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CERTIFICATE

This is to certify that the dissertation entitled **“Evaluation of Drivers and Barriers for Agent Technology in Manufacturing System”** being submitted by **Abhijeet Joshi (2015PIE5196)** is a bonafide work carried out by him under my supervision and guidance, andhence approved for submission to the **Department of Mechanical Engineering, Malaviya National Institute of Technology Jaipur** in partial fulfillment of the requirements for the award of the degree of **Master of Technology (M.Tech.)** in **Industrial Engineering**. The matter embodied in this dissertation report has not been submitted anywhere else for the award of any other degree or diploma.

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June 2017

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CANDIDATE’S DECLARATION

I hereby declare that the work which is being presented in this dissertation entitled **“Evaluation of Drivers and Barriers for Agent Technology in Manufacturing System”** in partial fulfilment of the requirements for the award of the degree of **Master of Technology (M.Tech.)** in **Industrial Engineering**, and submitted to the **Department of Mechanical Engineering, Malaviya National Institute of Technology Jaipur** is an authentic record of my own work carried out by me during a period of two years from July 2015 to June 2017 under the guidance and supervision of **Dr. Gunjan Soni** of the Department of Mechanical Engineering, Malaviya National Institute of Technology Jaipur.

The matter presented in this dissertation embodies the results of my own work and has not been submitted anywhere else for the award of any other degree or diploma.

Abhijeet Joshi
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This is to certify that the above statement made by the candidate is correct to the best of my knowledge.

Place: Jaipur
Dated: June, 2017

Dr. Gunjan Soni
Supervisor

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ABSTRACT

Technological advancement in the manufacturing system in current scenario is inevitable due to today's customer driven and volatile nature of the market. The implementation of agent technology in a manufacturing system increases the flexibility which handles uncertainty generated due to advance technology. Therefore in this dissertation work, the critical drivers affecting implementation of agent technology are identified and the relationships among different critical drivers are analysed for a manufacturing system. Apart from this barriers involved in implementation of agent technology are also identified and evaluated. Interpretive structural modelling (ISM) and MICMAC analysis are adopted for analysing their inter-relationships for both critical drivers and barriers individually. A structural model is developed for providing rank to the identified critical drivers and barriers. Also driving-dependent power diagram is presented for analysing the behaviour of different critical drivers and barriers separately. This dissertation work also comprised of a case study in which a detailed survey through three different industries have been done. The three manufacturing firms are compared on the basis of the most influential critical drivers and barrier. For the comparison of three manufacturing firms a MCDM (multi criteria decision making) technique that is grey approach is being used.

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CHAPTER 1

INTRODUCTION

1.1 Overview

With the global competition and rapid change in customer needs and requirements is a major factor behind the changing in the production styles. Todays manufacturing system cannot survive with the traditional workflow and enviornment. The traditional approaches limits the expandability and reconfigurability of the manufacturing systems (Shen, W. et al., 2006). Also the increased customization and shorter life cycle of the product has been pushing towards the new approach which can withstand in the dynamic enviornment (Rizvan Erola et al., 2012).The conventional manufacturing systems are incapable to exhibit these capabilities of responsiveness, flexibility, robustness and re-configurability, since they are made on hierarchical and centralized control structures that present good production optimization, but a weak response to change due to the rigidity and centralization of their control structures. Such centralized hierarchical organization normally leads to situations where the whole system is shutting down by single failures at one point of the system hierarchy (Paulo letieo 2008; Colombo et al., 2006).Thus there is a need of a system which is more robust more flexible which suits the present competitive world in a much better way with more accuracy and productivity for improved quality and greater customer satisfaction and all this will be achieved with the help of introduction of agent technology in the manufacturing system.

1.2 Concept of agent technology

An agent is anything that can be viewed as perceiving its environment through sensors and acting upon that environment through actuators (Odell, J., 2002).

- Human agent: eyes, ears, and other organs for sensors; hands, legs, mouth, and other body parts for actuators
- Robotic agent: cameras and infrared range finders for sensors; various motors for actuators

- Software agent: keystrokes, file content & network places as sensors
- Actuators are display on screen, writing files, and sending network places.

An intelligent agent chooses how to act not only based on the current percept, but the percept sequence. An agent should strive to "do the right thing", based on what it can perceive and the actions it can perform. The right action is the one that will cause the agent to be most successful.

An agent operates in an environment from which it is clearly separated (Figure 1.1). Hence, an agent (1) makes observations about its environment, (2) has its own knowledge and beliefs about its environment, (3) has preferences regarding the states of the environment, and finally, (4) initiates and executes actions to change the environment.

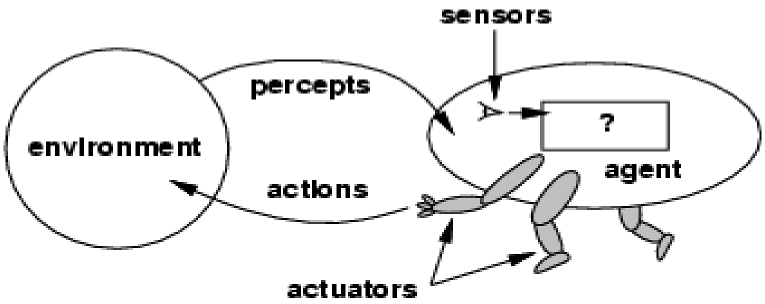

Figure 1.1 Interaction of agent with its enviornment

An agent is a computational system that is situated in a dynamic environment and is capable of exhibiting autonomous and intelligent behavior (L. Monostori J. et al.,2006).

1.3 Manufacturing system

A manufacturing system comprises the arrangement of manufacturing equipment in certain manner. It has a physical layout (job-shop, flow-shop, cellular system and project-shop) tangibly while production control operates on production philosophies intangibly. The important elements of a manufacturing system are material transfer, methods of information and energy which includes performance measures of the system (Chryssolouris, 2006). Today’s manufacturing environment is highly uncertain as well as continuously changing which is characterised by shorter life cycles of products and technologies, shorter lead time, increased customised price of standard product, increased product variety & quality and extreme global competition. The researchers agree that the level of uncertainty will be growing continuously in the coming years (D’Souza and Williams, 2000; Urtasun-Alonso et al., 2012). Prospectively, the manufacturing industries which are highly flexible will satisfy customer demand rapidly with continuous changing customer requirements (Winkler, 2009; Winkler and Seebacher, 2011). Hence, manufacturing systems must be much more flexible to changing product variety and production volume conditions (Zhang et al., 2003).

1.4 Objectives

The objective of this thesis work are as follows:

- To identify the drivers of agent technology and analyse the relationship among them in manufacturing system.
- To identify the barriers of agent technology and analyse the relationship among them in manufacturing system.
- To compare three manufacturing firms on the basis of identified drivers and barriers.

1.5 Organisation of Thesis

*1. **Introduction***

A brief introduction of agent and manufacturing systems has been presented in this chapter. Further, importance and dominance of agent based manufacturing over the other manufacturing techniques has been discussed.

*2. **Literature Review***

The previous studies pertaining to agent technology and the application of agent technology in manufacturing system has been reviewed in this chapter. The research gap in the current studies has been revealed and based upon that gap an objective has been presented.

3. ***Drivers of Agent technology in Manufacturing System***

This chapter comprised of identification of drivers and then discussion of various drivers. Furthur in this chapter there is a breif introduction of interpretive structural modelling and then the ISM technique has been employed on the different drivers identified.

4. ***Barriers of Agent technology in Manufacturing System***

This chapter comprised of identification of barriers and then discussion of various barriers identified. Latter on in this chapter ISM technique has been employed on the different barriers identified.

5. ***Case Study***

This chapter deals with the case study of comparing three manufacturing firms on the basis of influential drivers and barriers of agent technology with the help of grey approach.

6. ***Conclusion***

The conclusions formed on the basis of the results obtained along with the future scope of work are discussed in this chapter.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

An overview of the investigations on the agent based manufacturing system has been in this section. This literature review comprised of the application of agent technology this section. This literature review comprised of the application of agent technology in manufacturing system that is how agent technology has been playing major role in today's manufacturing system. Its various application in the field of manufacturing also in this literature review we have identified the key factors of agent based manufacturing system. Key factors are the parameters which can be employed to compare between two or more companies.

2.2 Application of Agent Technology in Manufacturing System

Several research articles widely discussed flow shop and job-shop problems in manufacturing systems by scheduling perspective. Babayan and He (2004) adopted agent technology based cooperation in scheduling system to solve n-job three-stage flexible flow-shop scheduling problem. Weng and Fujimura (2010) provided solutions for dynamic flow-shop scheduling problem using multi-agent feedbacks which collect real time information and accordingly make decisions and work interactively. A hybrid flow-shop scheduling problem is solved by Yue-wen et al. (2011) using multi-agent particle swarm optimisation. While Savino, Mazza and Neubert (2014) solved multi-objective flow-shop modelling and scheduling problem using multi-agent based coordination mechanism.

Alotaibi, Lohse and Vu (2016) introduced two types of uncertainty: machines breakdown and dynamic job arrival in to job-shop manufacturing system. Here the authors proposed a multi-agent based decision making and negotiation model to deal these uncertain events and solve dynamic bi-objective robustness for tardiness and energy in job-shop scheduling. Nouri, Driss and Ghédira (2016) presented two NP hard problems simultaneously; robot routing problem and job shop scheduling problem. This complex problem requires the use of agent technology. Therefore the authors had proposed hybrid meta-heuristics based on clustered holonic multi-agent model to solve above complex problem. Erol et al. (2012) proposed multi-agent based approach for real time scheduling of machines and automated guided vehicles in manufacturing system. In this approach the dynamic feasible schedules were generated through negotiation mechanisms between agents. Zhang and Wang (2016) addressed production scheduling problems in re-entrant manufacturing systems (RMSs) which have large scale complexity and dynamic uncertainty. A multi-agent based hierarchical collaborative system had been developed by the authors to improve the efficiency of RMSs. Antzoulatos et al. (2016) presented a multi-agent framework for industrial assembly systems in order to cope with frequently changing resources, resource capabilities and product specifications.

In all above research examples, the agent technology was used to deal with the complexities involved in the manufacturing systems. There are several factors that suggest the vital role of agents and agent technologies. Identification and description about factors of agent technology is given in following subsection.

2.3 Identification of drivers for agent technology

After scanning the plethora of literature related to agents and multi-agent systems, it may be pointed out that there is a lack of evidence in recent literature to suggest that the drivers or enablers of agent technology are yet to be discussed by the researchers. There are some authors who identified new technologies/ drivers to improve the efficiency of multi-agent systems in their articles but only Luck et al. (2005) described these new technologies collectively as critical drivers of agent technology at one place. In this dissertation work, seven technologies as critical drivers that can affect implementation of agent concept in manufacturing system are identified based on literature review and through discussion with related industry experts and academicians. The descriptions of critical drivers are as follows:

1) Semantic Web

Berners-Lee, Hendler and Lassila (2001) described semantic web as a developed version of present web on which data is stored and structured in such a way that it can be read by computer machines for the automatic processing in different applications. Garcı´a-Sa´nchez et al. (2009) presented SEMMAS, an ontology based framework for seamlessly integrating two technologies; Intelligent agents and Semantic web services for analysing the potential benefits of their combination. Hence Semantic web and agent technologies are intimately connected and enable to handle complex agent based computing in manufacturing systems.

2) Grid Computing

Foster and Kesselman (2004) referred the grid as a high performance computing infrastructure for supporting large scale distributed systems, information handling and knowledge management. Grid computing provides a virtual infrastructure to users with integrating data and computing resources for solving various types of problems (Blatecky 2002; Khan et al. 2017). The grid provides heterogeneous, distributed, unpredictable and autonomous resources that involve collaborative use of high-end computers, databases and networks owned and managed by multiple organisations. The flexibility is more generally the main benefit of grid computing (Garg, Buyya and Siegel 2010). Yang et al. (2016) proposed a grid based simulation environment i.e. Social Macro Scope (SOMAS) for supporting parallel exploration on agent based models with large parameter space and had done extensive experiments which confirmed effectiveness, practicability and good scalability of this grid computing based simulation environment for agent-based system models.

3) Peer-to-Peer Computing

Peer-to-Peer (P2P) computing provides an extensive range of infrastructures, systems, technologies and applications that share distributed resources to accomplish a function in a decentralized way Milojicic et al.(2002) surveyed the field of P2P computing systems and applications by analysing the design and implementation issues of P2P systems. This survey has helped the researchers by proposing potential benefits of P2P systems as a strong alternative for the requirements of anonymity, scalability and fault resilience. Purvis et al. (2003) presented a multi-agent based approach that supports multiple trader agents in electronic trading environments on multiple peer-to-peer computing platforms. Thus P2P computing drives multi-agent technology in manufacturing systems.

4) Ambient Intelligence

Ambient intelligence (AmI) is a popular research topic due its transparency, characteristics and intelligence. AmI can be described as an environment of large number of components which are independent and distributed interacting to each other and have characteristics of flexibility, autonomous, responsiveness, pro-activeness and so on which are the same as agents have. Thus AmI requires the agents to be able to interact with other agents in provided environment in order to achieve their aims. The AmI considers numerous different aspects and technologies in manufacturing domain (Sanders 2009; Sanders and Tewkesbury 2009). Robinson, Sanders and Mazharsolook (2015) described the intelligent systems using AmI for monitoring energy consumption and knowledge management technologies in manufacturing system. Hence AmI drives the agent technology in manufacturing systems.

5) Self-systems and Autonomic Computing

The computation systems which are able to cope themselves called as self-systems that include some features such as self-organisation, self-management, self-configurable, self-awareness, self-diagnosis and self-repair. Autonomic computing is defined as self-organising behaviour of distributed computing resources adapting to uncertain changes. Barbosa et al. (2015) proposed a multi-agent based adaptive holonic control architecture for distributed manufacturing systems that balances from a stationary state to transient state, inspired by biological and evolutionary theories. A two dimensional self-organised mechanism inspired by hierarchical and heterarchical control approaches was designed to handle unexpected events and modifications. Madureira et al. (2014) presented a negotiation mechanism based on swarm intelligence for self-organised dynamic scheduling in manufacturing systems. Thus self-systems give several application areas for agent technologies.

6) Web Services and Service Oriented Computing

This technology provides a standard way for interoperation between different software applications running on different platforms. According to Booth et al. (2004) web services came out as the best option for remote execution of functionality due to its properties such as ubiquity, independence of operating system and programming language and interoperability. Thus Web services and service oriented computing provide a well-established infrastructure which is widely accepted for supporting agent interactions using XML and HTTP interfaces in multi-agent manufacturing systems.

7) Complex Systems

A complex system consists of a large number of interacting components whose collective activity is non-linear with interdependency between components. Hsu et al. (2016) presented a study to understand the complexity in selection of project team member using agent-based modelling. Agent technologies conceptualise the complex systems as consisting interacting autonomous components, each acting, learning or evolving separately in response to interactions in their local surroundings. This conceptualisation includes the computer simulations of the system's operation and behaviours and design of control through agent concepts (Luck et al. 2005). Thus agent technologies give a proper way to handle increasing complexity in the modern manufacturing systems.

2.4 Identification of barriers

The barriers of agent based manufacturing system are obtained after going through a large literature. Barriers are the variables that restricts or impede the implementation of anything. In this chapter we are going to deal with different barriers of implementation of agent in the manufacturing system. The below discussed barriers are amongst the most important one.

1. Required Investment

The required investment is a major barrier in the implementation of agent based manufacturing system. Although it provides the flexibility in the manufacturing system but it is the only single most important factor that restricts the implementation of the agent in the manufacturing system (Marik, V., & McFarlane, D., 2005). Also the cost incurred in making the system interoperable is too high which restricts its implementation (L monostori et al., 2006). The first consideration for setting up anything any business or any manufacturing unit is the cost involved in the setting up of that business or manufacturing unit thus as there is a huge amount of money required for the setting up an agent in manufacturing system limits its implementation.

2. Scalability

Scalability is defined as the ability to change in size or scale and its plays an important role in reconfigurable manufacturing system (R nzi, C. et al., 2014). As there are hundreds or thousands of agent works together in a multi agent system with that much of parallel agent working there scalability is a major problem. To scale or synchronize the entire agent working in the manufacturing system is bit a tedious and sometimes also increases the complexity of the manufacturing system as to scale to or more agents there may be a need of another agent for their proper scale.

3. Engineering Education

Marik, V., & McFarlane, D. (2005) Nearly all control and system engineers have been taught to design, run, and maintain strictly centralized solutions. This is a serious barrier, because engineers employing these solutions (presented in the last three decades under the CIM label) aren’t really ready and able to support agent-based solutions. There is a need of different type of approach for deploying an agent into the manufacturing system we cannot only rely on the current education which only deals with the knowledge of one subject as we have to make a system where it adapts and learn. For make it work in an efficient way there must be a core understanding of machine learning and artificial intelligence which basically lacks in our current education system (Sun, S., Joy, M., & Griffiths, N., 2007)

4. Absence of Industrial Controller

There are missing methodologies for the implementation of agent in a manufacturing system that supports easy, fast, transparent and reusable integration of physical automation devices this absence of devices makes it difficult to implement (De Keyser, R., 2005). There is also a problem to control agent behaviour in a system. Sometimes an agent misbehaves or acts differently from its desired actions our current technologies which lacks in controlling the behaviour of an agent restricts or put up a barrier in its implementation.

5. High Complexity

The introduction of an agent makes the system complex anything which is difficult to understand seems to be complex and with such a great innovation and self learning capability makes it complex compared to the centralised solution also the system problem is same and remains intact thus an agent also fails to simplify the problem or the complexity of our system thus this is another barrier in the implementation of agent in the manufacturing system (Leitão, P., Mařík, V., & Vrba, P., 2013).

6. Lack of Awareness

The manufacturing sector is not aware about the need and importance of the agent in their manufacturing system. Its complexity and lack of engineering education also makes it difficult to understand and thus the top management involved shows less interest and awareness for the agent. They don't want to change and try to stick to their conventional manufacturing ways being not aware of the advantages provided by the agent in the manufacturing system (Bousbia, S., & Trentesaux, D., 2002)

7. Interoperability

Interoperability is a crucial factor in the development of distributed and heterogeneous production control applications. The solution to those problems requires the use of standard platforms that support transparent communication between distributed control components or applications. Ontologies play a decisive role to support interoperability problems. However, the development of an ontology may take from a few hours up to months or even years depending on the choice of the language, the covered topics, and the level of formality and precision (Borgo and Leita˜o, 2006).

8. Afraid of Complex Terminologies

Afraid of terminologies such as ontologies, self organization, emergence, distributed thinking and learning The introduction of agent in the system also brings out the different types of difficult terminologies which are harder to understand also it require a different type of learning to get acquaint with the agent it requires an integration of human with hardware and software of the system (Paolucci, M., & Sacile, R., 2016).

9. Fear of Failure

As the cost requirement is too high in deploying an agent there is always a fear of failure amongst the top management because the losses involved could be very disastrous. The top management has always a fear of acceptance as well as fear of losses if they could not cope up with the optimum results after the deployment of an agent thus this is one of the major barrier in the implementation of agent technology in the manufacturing system (Farmer, J. D., & Foley, D., 2009).

10. New Approach Required

The use of this system requires a new way of thinking and approaching the problem, which is in some situation difficult to apprehend and develop. Agent works on the foundation of flexibility, adaptability and learning thus with that sort of work there is requirement of constructing a different type of machine learning set or tool thus we require a new approach to deal with the implementation of agent technology in the manufacturing system (Metzger, M., & Polakow, G., 2011).

11. Commercial Platform

The control systems offered by the major vendors support only centralized control solutions. The wider application of agent-based solutions will require the migration toward autonomous, independent controllers communicating asynchronously (when needed) among themselves in a peer-to-peer way. However, this migration problem remains unsolved (Marik, V., & McFarlane, D., 2005). Thus this disintegration in the whole system brings the threat to agent technology implementation also if the agent has to be deployed it should work in a manner that it should able to make sequential steps for each and every level of a supply chain.

CHAPTER 3

ANALYSIS OF DRIVERS FOR AGENT TECHNOLOGY

3.1 Overview

The drivers of agent technology are discussed earlier in the literature review section. The drivers identified are semantic web, grid computing, peer to peer computing, ambient intelligence, self system and autonomic computing, web services and service oriented computing and complex systems. All the above drivers are analysed using ISM approach and a interrelationship among all the drivers are obtained. In this chapter a brief review of ISM approach is being presented also MICMAC analysis is being done on the above identified drivers and finally a driving dependence diagram is developed.

3.2 Brief review of ISM

Interpretive structural modelling has been used by many authors and researchers to analyse the relationships between drivers/enablers for developing more understanding about the systems under consideration. The studies used ISM approach in different applications, are as follows: Shankar and Suhaib (2008) presented a study to understand the mutual interrelationships between enablers of flexible manufacturing system (FMS) and identify the drive and dependent enablers of FMS. Faisal, Banwet and Shankar (2006) presented hierarchy based ISM approach for modeling the enablers of supply chain risk mitigation to understand the dynamics among different enablers which help to mitigate the risk in supply chain. Diabat and Govindan (2011) developed a model for the drivers of green supply chain management using ISM framework. Bhanot, Rao and Deshmukh (2017) presented a study that aims to strengthen drivers and mitigate the barriers of sustainable manufacturing using an integrated approach of Decision-making Trial and Evaluation Laboratory approach, Maximum mean de-entropy algorithm, Structural equation modelling and Interpretive structural modelling. Chang, Hu and Hong (2013) presented a research for identifying key agile factors to introduce new product in mass production using a hybrid approach of ISM and Analytical Network Process (ANP).

ISM was used to identify and analyse the interrelationship between the agile factors while ANP was employed to rank the importance of all factors. To analyse the risks in perishable food supply chain and to determine the most effective risk mitigation strategies Prakash et al. (2017) described a methodology using ISM. Through this methodology all types of involved risks in this supply chain are modelled. Mannan, Khurana and Haleem (2016) presented a study to analyse the critical factors using ISM approach for integrating sustainability with innovation considering Indian manufacturing SMEs. Agi and Nishant (2017) discussed a study on understanding the prominent factors on the implementation of green supply chain management practices and analyse the interrelations between these factors using ISM approach. Hence ISM approach has been adopted by the researchers in several areas but the analysis of drivers of agent technology using ISM methodology has not been investigated yet.

After scanning the related literature it can be pointed out that the analysis of interrelationships between the drivers of agent based manufacturing systems is yet to be discussed. Therefore in this research, the interactions between critical drivers of agent technology have been analysed for manufacturing systems using ISM approach.

3.3 ISM Methodology

ISM methodology is used as a communication tool in the complex systems to manage decision making. The management of manufacturing systems involves several elements associated with physical components and decision making which complicates the system’s structure. It becomes difficult to handle such type of system which does not describe its structure clearly. Hence it is required to develop a methodology that can identify interrelationship among various elements in the system. Thus ISM is a learning process in which a set of related elements are interacted and organised into a comprehensive systemic model (Warfield, 1974; Sage, 1977).

ISM is a type of group learning process in which a group of people they may be the experts of the particular field or the analyst of that particular problem, they sit and decide whether and how the drivers are related through their judgment and thus make it an interpretive technique. The steps involved in ISM approach are given below. The flow chart of ISM methodology is shown in the figure 3.1.

Step1: The critical drivers affecting the implementation of agent technology for the manufacturing system under study are listed. After this a contextual relationship is developed for each pair of critical drivers.

Step2: A structural self-interaction matrix (SSIM) is developed for the critical drivers, which indicates pair wise interactions among critical drivers of agent technology.

Step3: A reachability matrix is developed from the SSIM.

Step4: The reachability matrix is partitioned in to different levels.

Step5: The reachability matrix is now converted in to conical matrix.

Step6: Based on above relationships an ISM model is developed.

Step7: Check conceptual inconsistency in the ISM model and necessary alterations are incorporate

ISM methodology is applied to the manufacturing system under study. The description of each step which leads to development of ISM model is depicted on the next page.

3.3.1 *Development* of *SSIM*

After finding the contextual relationships among the critical drivers, a structural self-interaction matrix (SSIM) is prepared based on pair-wise comparison of drivers of the system under consideration. The SSIM was discussed in the decision team to achieve the consensus. SSIM has been finalized based on the responses of decision team and it is presented in Table 3.1.

For examining different critical drivers of agent technology "leads to" type relationship is adopted. This means that one driver that may be termed as 'i' leads to 'j' which is the other driver.

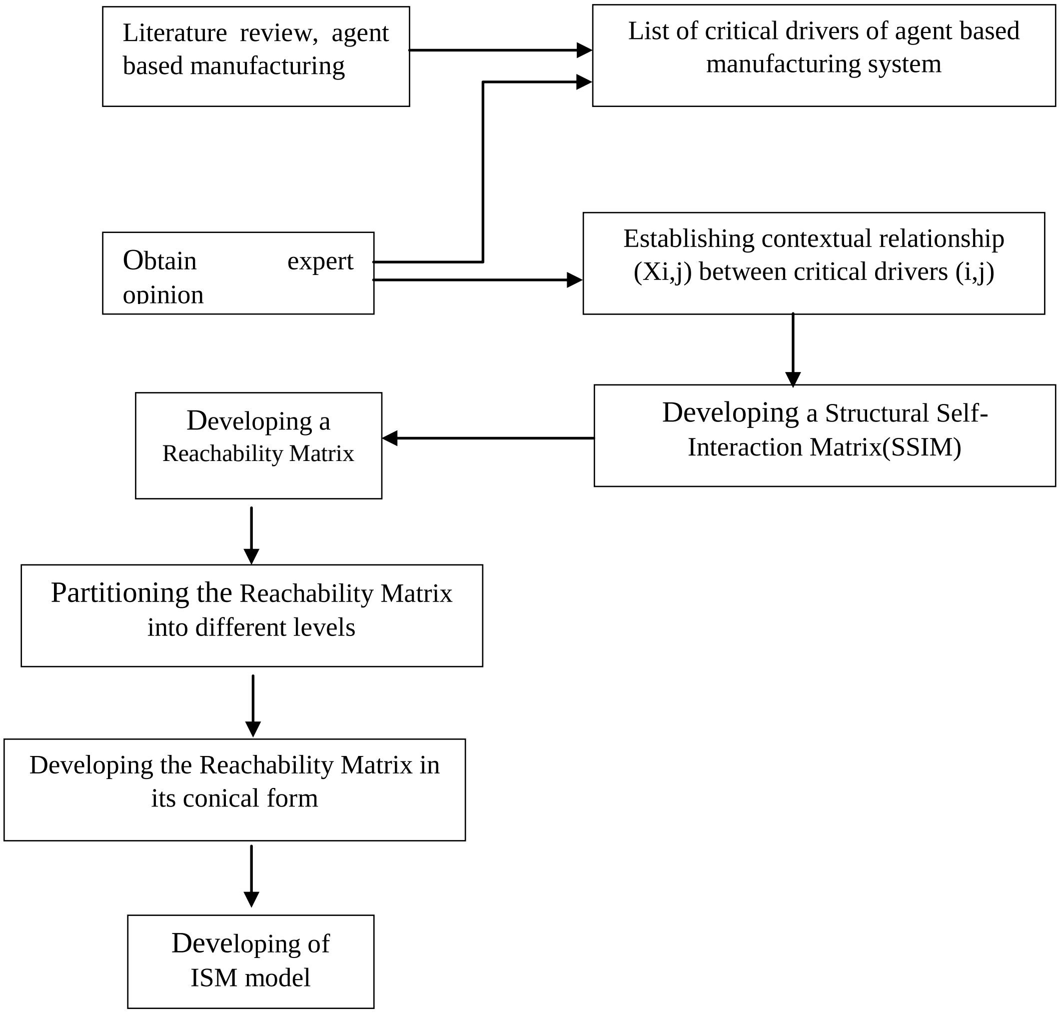

Figure 3.1 Flow chart of ISM methodology for drivers

The following four symbols have been used to denote the direction of relationship between critical drivers (i and j):

V— driver i will lead to achieve driver j;

A— driver j will lead to achieve driver i;

X— driver i and j will lead to achieve each other; and

O— driver j and i are unrelated.

Table 3.1 Structural Self-Interaction Matrix (SSIM) for drivers

Elements	7	6	5	4	3	2	1
1. Semantic Web	V	X	O	O	V	V	X
2. Grid Computing	V	X	O	V	A	X	
3. Peer to Peer Computing	V	A	A	V	X		
4. Ambient Intelligence	X	A	X	X			
5. Self-System & Autonomic Computing	V	A	X				
6. Web Services & Service Oriented Computing	V	X					
7. Complex Systems	X						

3.3.2 *Developing Reachability matrix*

The SSIM has been converted into a binary matrix, called reachability matrix by replacing V, A, X and O by 1 and 0 as per given case. The substitution of 1 and 0 are as per the following rules (Soni and Kodali , 2016):

- 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;

- If the (i, j) entry in the SSIM is A, then the (i, j) entry in the reachability matrix becomes 0 and the (j, i) entry becomes 1;

- If the (i, j) entry in the SSIM is X, then the (i, j) entry in the reachability matrix becomes 1 and the (j, i) entry also becomes 1; and

- If the (i, j) entry in the SSIM is O, then the (i, j) entry in the reachability matrix becomes 0 and the (j, i) entry also becomes 0.

Following the above rules, the reachability matrix is developed as shown in Table 3.2.

Table 3.2 Reachability Matrix for drivers

Elements	**1**	**2**	**3**	**4**	**5**	**6**	**7**
1. Semantic Web	1	1	1	0	0	1	1
2. Grid Computing	0	1	0	1	0	1	1
3. Peer to Peer Computing	0	1	1	1	0	0	1
4. Ambient Intelligence	0	0	0	1	1	0	1
5. Self-System & Autonomic Computing	0	0	1	1	1	0	1
6. Web Services & Service Oriented Computing	1	1	1	1	1	1	1
7. Complex Systems	0	0	0	1	0	0	1

3.3.3 Developing Level partitions

Now moving ahead for another step of ISM technique in which the reachability and antecedent set for each of the critical driver from the final reachability matrix are obtained. The reachability set is composed of the element itself and the other element which it may affect, on the other hand the antecedent set consist of the element itself and the other element which may affect it. For acquiring the top level hierarchy in ISM model the element in the reachability set and intersection set should be same where intersection set is composed of the intersection of reachability set and antecedent set. The top level element will not lead to achieve or impact any other element above their own level in the hierarchy and thus once they are obtained, they will be discarded from the set of other elements (Table 3.4) and similarly through series of iterations the other levels of ISM hierarchy is found out. The results for iteration II to V are summarised in Table 3.7. The obtained levels of ISM technique are now used for the construction of the ISM model.

Table 3.3 Level partitions- I iteration for drivers

Elements	Reachability Set	Antecedent Set	Intersection Set	Levels
1	1,2,3,6,7	1,6	1,6	
2	2,4,6,7	1,2,3,6	2,6	
3	2,3,4,7	1,3,5,6	3	
4	4,5,7	2,3,4,5,6,7	4,5,7	I
5	3,4,5,7	4,5,6	4,5	
6	1,2,3,4,5,6,7	1,2,6	1,2,6	
7	4,7	1,2,3,4,5,6,7	4,7	I

Table 3.4 Level partitions- II iteration for drivers

Elements	Reachability Set	Antecedent Set	Intersection Set	Levels
1	1,2,3,6	1,6	1,6	
2	2,6	1,2,3,6	2,6	II
3	2,3	1,3,5,6	3	
5	3,5	5,6	5	
6	1,2,3,4,5,6	1,2,6	1,2,6	

Table 3.5 Level partitions- III iteration for drivers

Elements	Reachability Set	Antecedent Set	Intersection Set	Levels
1	1,3,6	1,6	1,6	
3	3	1,3,5,6	3	III
5	3,5	5,6	5	
6	1,2,3,6	1,2,6	1,2,6	

Table 3.6 Level partitions- IV iteration for drivers

Elements	Reachability Set	Antecedent Set	Intersection Set	Levels
1	1,6	1,6	1,6	IV
5	5	5,6	5	IV
6	1,5,6	1,6	1,6	V

Table 3.7 Level partitions- final iteration

Elements	Reachability Set	Antecedent Set	Intersection Set	Levels
1	1,2,3,6,7	1,6	1,6	IV
2	2,4,6,7	1,2,3,6	2,6	II
3	2,3,4,7	1,3,5,6	3	III
4	4,5,7	2,3,4,5,6,7	4,5,7	I
5	3,4,5,7	4,5,6	4,5	IV
6	1,2,3,4,5,6,7	1,2,6	1,2,6	V
7	4,7	1,2,3,4,5,6,7	4,7	I

3.3.4 *Developing conical matrix*

For developing a conical matrix (in Table 3.8) the variables are clustered in the same level across row and column of final reachability matrix. The dependence power of critical driver is defined by summing up of number of ones in the column likewise the driving power is obtained by adding the number of ones in the row. Moving ahead rank of driving power and dependence power is obtained of critical drivers having maximum sum in the rows and column accordingly.

Table 3.8 Conical Matrix for drivers

Critical Drivers	**4**	**7**	**2**	**3**	**1**	**5**	**6**	**Driving Power**	**Rank**
4	1	1	0	0	0	1	0	3	IV
7	1	1	0	0	0	0	0	2	V
2	1	1	1	0	0	0	1	4	III
3	1	1	1	0	0	0	0	4	III
1	0	1	1	1	1	0	1	5	II
5	1	1	0	1	0	1	0	4	II
6	1	1	1	1	1	1	1	7	I
Dependence Power	6	7	4	4	2	3	3		
Rank	II	I	III	III	V	IV	IV		

3.3.5 *Development of ISM model*

The development of ISM model involves the ISM hierarchical level in which the critical drivers are placed. Level-I of ISM model is placed at the top and level-V is at the bottom. Critical driver ‘web services and service oriented computing’ (6) coming in the level V and having the highest driving power placed at the lowest level of ISM model similarly critical driver ambient intelligence (4) and complex systems (7) coming under level I and having highest dependence power are placed at the top of the ISM model and accordingly whole ISM model has been developed in figure 3.2.

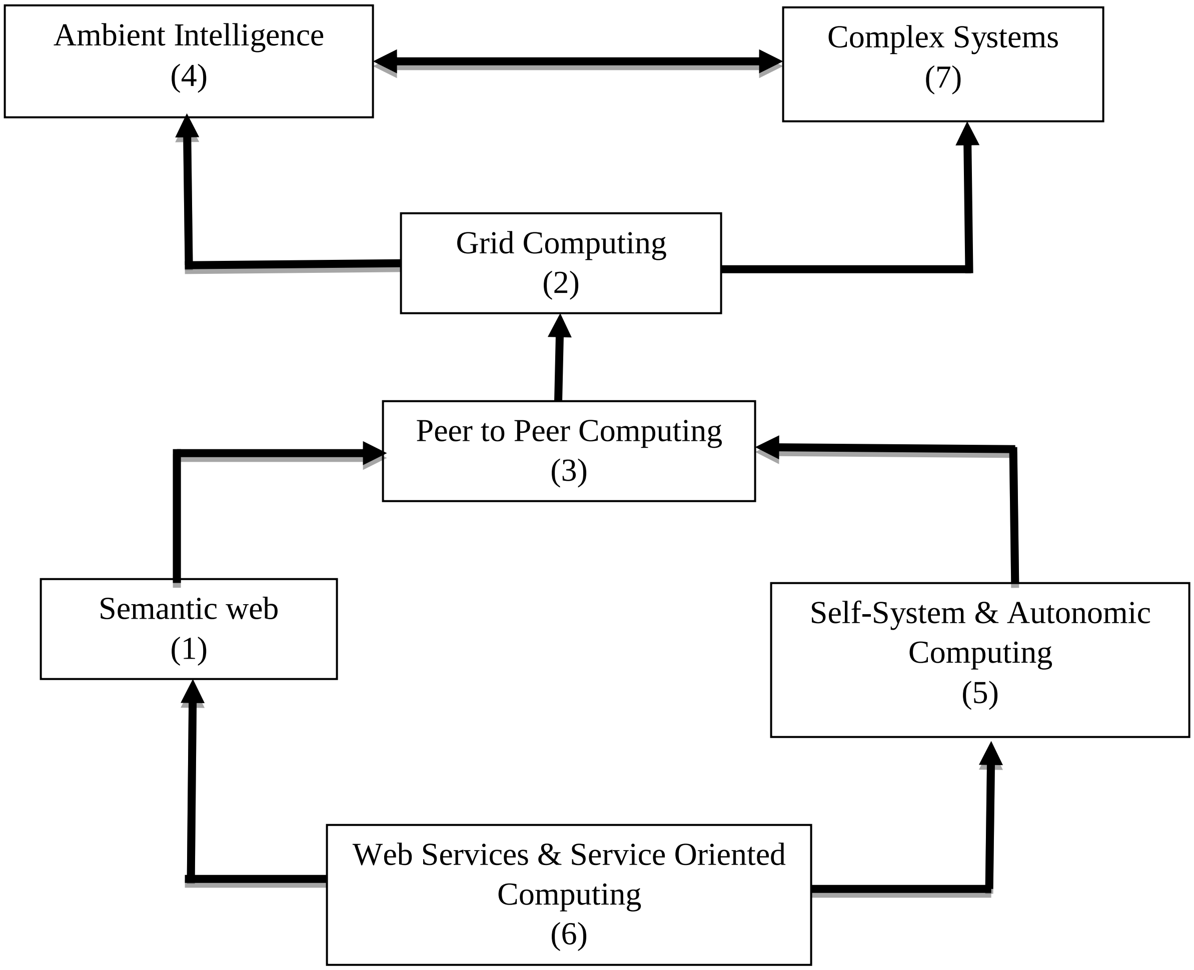

Figure 3.2 ISM Model for drivers

3.4 MICMAC analysis

The purpose of MICMAC analysis Mandal and Deshmukh (1994) in this research is to analyse the critical drivers of agent technology according to their driving and dependence power in considered manufacturing system. The critical drivers are classified in four categories based on their driving power and dependence power.

I. *Autonomous drivers:* These have weak driving and weak dependence power. These drivers are relatively disconnected from the ISM implementation process.

II. *Dependent drivers:* It consists of dependent critical drivers that have weak driving power and strong dependence. In this category of drivers, two critical drivers (i.e. ambient intelligence and complex systems) are placed.

III. *Linkage drivers:* This category of drivers includes strong driving power as well as strong dependence power. Two critical drivers (i.e. grid computing and peer-to-peer computing) are found in this category.

IV. *Independent drivers:* These types of drivers have strong driving power and weak dependence power. These are generally called as ‘key drivers’. Three critical drivers (i.e. semantic web, web services & service oriented computing and self-systems & autonomic computing) are found in this type of drivers.

The driving power and dependence power of critical drivers are given in conical matrix as in Table 3.8. After doing MICMAC analysis the driving power-dependence power diagram is drawn in Figure 3.3. This diagram is divided in to four categories. First category includes ‘autonomous drivers’ second contains ‘dependent drivers’, third comprises of ‘linkage drivers’ and ‘independent drivers’ are in fourth category. From Table 3.8 it is observed that critical driver (6) has driving power of 7 and dependence power of 3. Hence in figure 3 it is positioned at a place corresponding to driving power of 7 and dependence power of 3 which is in part IV. Similarly other drivers are placed in this diagram.

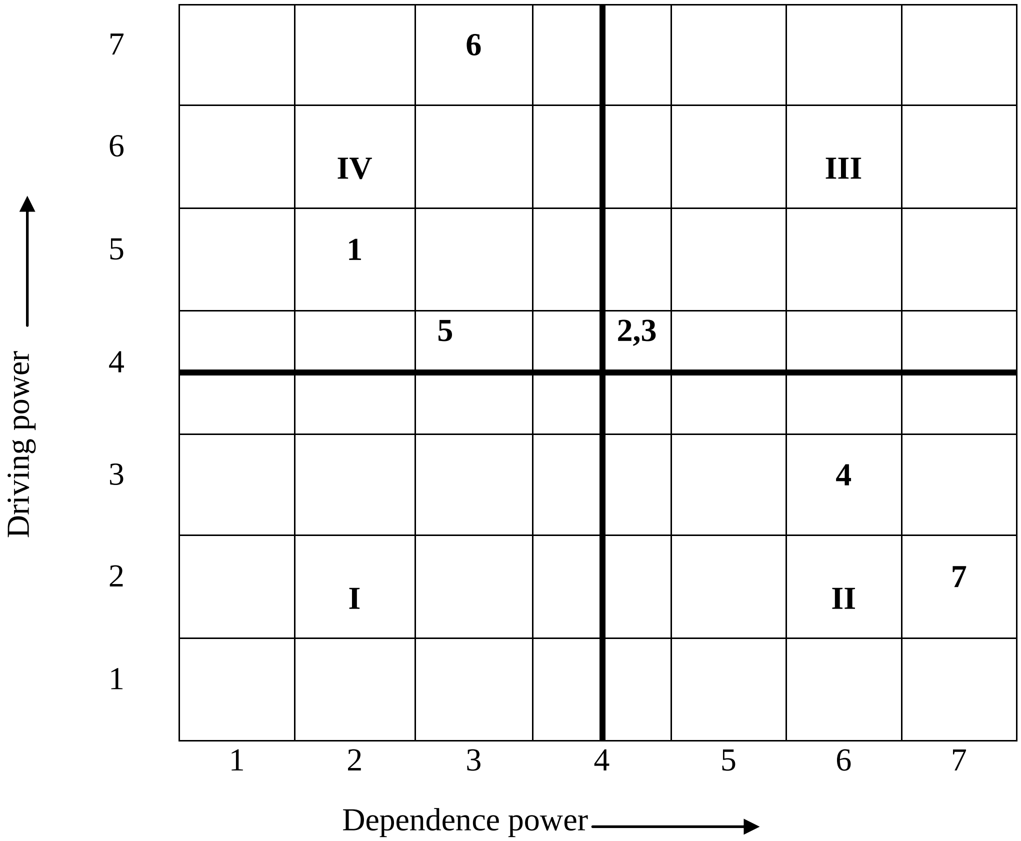

Figure 3.3 Driving power-dependence power diagram for drivers

3.5 Results and discussions

The concept of agent technology (AT) is a very important topic for the practitioners and researchers. AT Implementing in a manufacturing system is challenging and tough or costly to implement. A range of AT drivers can make it easy to accomplish successful AT implementation. It needs to investigate the effect of these drivers and to find the inter-relationships between the drivers during AT implementation. Hence the manufacturing industries also need to define most effective driver for AT implementation.

The main objective of this study is to identify and define inter-relationships among all selected critical drivers of agent technology and further to analyze drive and dependence power of those critical drivers for successful AT implementation in a manufacturing system. To achieve these goals, ISM methodology has been deployed in order to understand the relationships among critical drivers completely so that the management of the manufacturing firm may give more stress on those drivers which are more influential for AT implementation. It will help to deal uncertainty in the manufacturing system, which improves its flexibility and simultaneously customer satisfaction will also be achieved.

In this study ISM-MICMAC approach is used since binary relationships among selected critical drivers are being done by ISM while MICMAC approach describes sensitive analysis of driving and dependence behavior of drivers. It has been observed from ISM model (Figure 3.2) that the ambient intelligence and complex systems are at the first (Top) level of ISM model. The ambient intelligence requires the agents to interact other agents to fulfill their goals and complex systems involve complexity of modern software systems which can only be tackled by agents in the manufacturing system. Hence lack of these two drivers leads to lack of grid computing at level 2 and lack of peer-to-peer computing at level 3. Level 4 constitutes semantic web and self-system & autonomic computing in AT implementation in a manufacturing system. Finally web services & service oriented computing forms level 5 which is bottom level of ISM model.

Another objective of this research work was to analyze the driving and dependence power of the critical drivers that affect the AT implementation in a manufacturing system by MICMAC analysis. In MICMAC analysis, drivers are classified into four categories (Figure 3.3). The driving-dependence power diagram (Figure 3.3) shows that no critical drivers are found in the category of autonomous drivers. It concludes that all the critical drivers influence the AT implementation in a manufacturing system. The ambient intelligence and complex systems are weak drivers but strong dependent on other drivers (Figure 3.3- category II). These drivers are considered as important because these are shown in top level of ISM model. Their strong dependencies indicate that they require other critical drivers (Figure 3.3-category IV) to maximize the effect of these critical drivers in AT. Therefore the management should give high importance to these drivers. Two drivers i.e. grid computing and peer-to-peer computing are strong driver and strong dependent on others (Figure 3.3-category III). Any change in these drivers will affect other drivers and also give a feedback to them. Figure 3.3-category IV indicates the semantic web, self-system & autonomic computing and web services & service oriented computing are strong driver and weak dependent on others. It means that the management needs focus on these drivers more cautiously. It has been observed that these critical drivers help to attain other drivers which are at the top level of ISM model.

CHAPTER 4

ANALYSIS OF BARRIERS FOR AGENT TECHNOLOGY

4.1 Overview

The barriers of agent technology are discussed earlier in the literature review section. The barriers identified are required investment, scalability, engineering education, absence of industrial controller, lack of awareness, high complexity, interoperability, commercial platform, afraid of complex terminologies, new approach required and fear of failure. All the above barriers are analysed using ISM approach and interrelationship among all the barriers are obtained. In this chapter a brief review of ISM approach is being presented also MICMAC analysis is being done on the above identified bariers and finally a driving dependence diagram is developed.

4.2 ISM Methodology

ISM methodology as earlier described is a tool that is used for decision making in a complex system. it is required to develop a methodology that can identify interrelationship among various elements in the system. Thus ISM is a learning process in which a set of related elements are interacted and organised into a comprehensive systemic model (Warfield, 1974; Sage, 1977).

ISM is a type of group learning process in which a group of people they may be the experts of the particular field or the analyst of that particular problem, they sit and decide whether and how the drivers are related through their judgment and thus make it an interpretive technique. The steps involved in ISM approach are given below. The flow chart of ISM methodology is shown in the figure 4.1.

Step 1: The barriers affecting the implementation of agent technology for the manufacturing system under study are listed. After this a contextual relationship is developed for each pair of barriers.

Step 2: A structural self-interaction matrix (SSIM) is developed for the barriers, which indicates pair wise interactions among barriers of agent technology.

Step 3: A reachability matrix is developed from the SSIM.

Step 4: The reachability matrix is partitioned in to different levels.

Step 5: The reachability matrix is now converted in to conical matrix.

Step 6: Based on above relationships an ISM model is developed.

Step 7: Check conceptual inconsistency in the ISM model and necessary alterations are incorporated.

Now ISM methodology is applied to manufacturing system under study. The description of each step which leads to development of ISM model is as below.

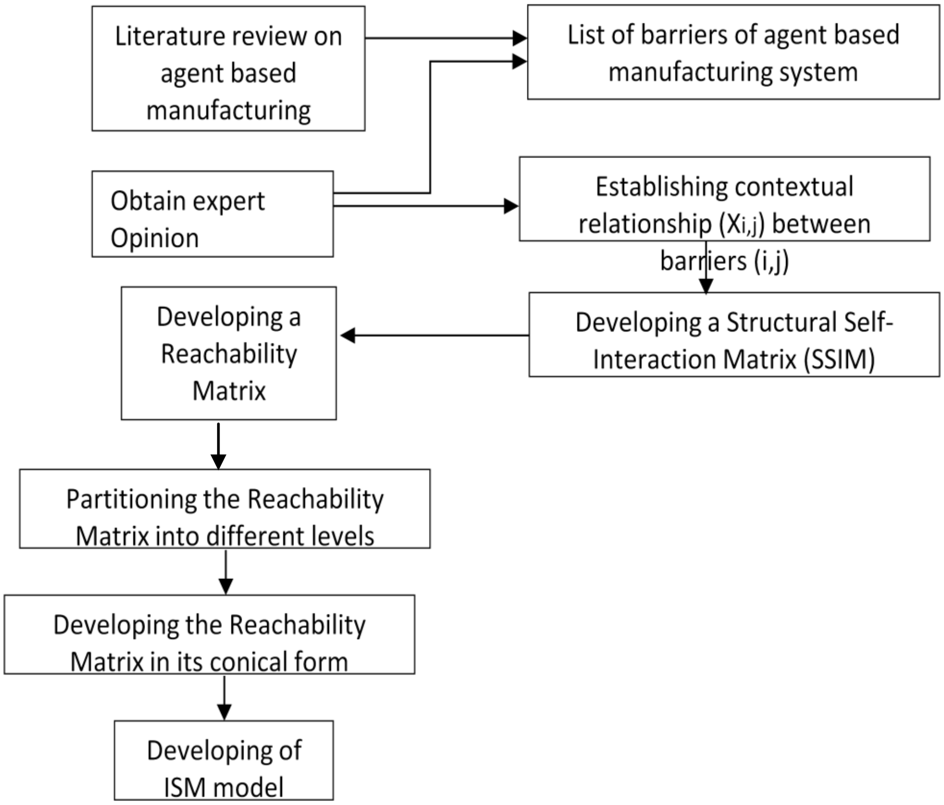

Figure 4.1 Flow chart of ISM methodology for barriers

4.2.1 *Development* of *SSIM*

After finding the contextual relationships among the barriers, a structural self-interaction matrix (SSIM) is prepared based on pair-wise comparison of barriers of the system under consideration. The SSIM was discussed in the decision team to achieve the consensus. SSIM has been finalized based on the responses of decision team and it is presented in Table 4.1.

For examining different barriers of agent technology “leads to” type relationship is adopted. This means that one driver that may be termed as ‘i’ leads to ‘j’ which is the other driver. The following four symbols have been used to denote the direction of relationship between critical drivers (i and j):

V— barrier i will lead to achieve barrier j;

A— barrier j will lead to achieve barrier i;

X— barrier i and j will lead to achieve each other; and

O— barrier j and i are unrelated

Table 4.1 Structural Self-Interaction Matrix (SSIM) for barriers

Elements	11	10	9	8	7	6	5	4	3	2	1
1. Required Investment	V	V	V	O	O	V	O	O	V	O	X
2. Scalability	V	V	V	O	O	O	V	V	O	X	
3. Engineering Education	O	A	O	O	O	A	A	A	X		
4. Absence of Industrial Controller	A	O	V	O	X	X	A	X			
5. High Complexity	X	V	X	X	A	X	X				
6. Lack of Awareness	X	V	V	V	O	X					
7. Interoperability	O	O	V	V	X						
8. Afraid of Complex Terminologies	O	V	O	X							
9. Fear of Failure	A	O	X								
10. New Approach Required	A	X									
11. Commercial Platform	X										

4.2.2 Developing *Reach ability matrix*

The SSIM has been converted into a binary matrix, called reachability matrix by replacing V, A, X and O by 1 and 0 as per given case. The substitution of 1 and 0 are as per the following rules (Soni and Kodali 2016):

- 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;

- If the (i, j) entry in the SSIM is A, then the (i, j) entry in the reachability matrix becomes 0 and the (j, i) entry becomes 1;

- If the (i, j) entry in the SSIM is X, then the (i, j) entry in the reachability matrix becomes 1 and the (j, i) entry also becomes 1; and

- If the (i, j) entry in the SSIM is O, then the (i, j) entry in the reachability matrix becomes 0 and the (j, i) entry also becomes 0.

Following the above rules, the reachability matrix is developed as shown in Table

Table 4.2 Reachability Matrix for barriers

Elements	1	2	3	4	5	6	7	8	9	10	11
1. Required Investment	1	0	1	0	0	1	0	0	1	1	1
2. Scalability	0	1	0	1	1	0	0	0	1	1	1
3. Engineering Education	0	0	1	0	0	0	0	0	0	0	0
4. Absense of Industrial Controller	0	0	1	1	0	1	1	0	1	0	0
5. High Complexity	0	0	1	1	1	1	0	1	1	1	1
6. Lack of Awareness	0	0	1	1	1	1	0	1	1	1	1
7. Interoperability	0	0	0	1	1	0	1	1	1	0	0
8. Afraid of Complex Terminologies	0	0	0	0	1	0	0	1	0	1	0
9. Fear of Failure	0	0	0	0	1	0	0	0	1	0	0
10. New Approach Required	0	0	1	0	0	0	0	0	0	1	0
11. Commercial Platform	0	0	0	1	1	1	0	0	1	1	1

4.2.3 Developing Level partitions

Now moving ahead for another step of ISM technique in which the reachability and antecedent set for each of the barriers from the final reachability matrix are obtained. The reachability set is composed of the element itself and the other element which it may affect, on the other hand the antecedent set consist of the element itself and the other element which may affect it. For acquiring the top level hierarchy in ISM model the element in the reachability set and intersection set should be same where intersection set is composed of the intersection of reachability set and antecedent set. The top level element will not lead to achieve or impact any other element above their own level in the hierarchy and thus once they are obtained, they will be discarded from the set of other elements (Table 4.4) and similarly through series of iterations the other levels of ISM hierarchy is found out. The results for iteration II to V are summarised in Table 4.8. The obtained levels of ISM technique are now used for the construction of the ISM model.

Table 4.3 Level partitions- I iteration for barrier

Elements	Reachability Set	Antecedent Set	Intersection Set	Levels
1	1,3,6,9,10,11	1	1	
2	2,4,5,9,10,11	2	2	
3	3	1,3,4,5,6,10	3	I
4	3,4,6,7,9	2,4,5,6,7,11	4,6,7	
5	3,4,5,6,8,9,10,11	2,5,6,7,8,9,11	5,6,8,9,11	
6	3,4,5,6,8,9,10,11	4,5,6,11	4,5,6,11	
7	4,5,7,8,9	4,7	4,7	
8	5,8,10	5,6,7,8	5,8	
9	5,9	2,4,5,6,7,9,11	5,9	I
10	3,10	1,2,5,6,8,10,11	10	
11	4,5,6,9,10,11	2,5,6,11	5,6,11	

Table 4.4 Level partitions- II iteration for barrier

Elements	Reachability Set	Antecedent Set	Intersection Set	Levels
1	1,6,10,11	1	1	
2	2,4,5,10,11	2	2	
4	4,6,7	2,4,5,6,7,11	4,6,7	II
5	4,5,6,8,10,11	2,5,6,7,8,11	5,6,8,11	
6	4,5,6,8,10,11	4,5,6,11	4,5,6,11	
7	4,5,7,8	4,7	4,7	
8	5,8,10	5,6,7,8	5,8	
10	10	1,2,5,6,8,10,11	10	II
11	4,5,6,10,11	2,5,6,11	5,6,11	

Table 4.5 Level partitions- III iteration for barrier

Elements	Reachability Set	Antecedent Set	Intersection Set	Levels
1	1,6,11	1	1	
2	2,4,5,11	2	2	
5	5,6,8,11	2,5,6,7,8,11	5,6,8,11	III
6	5,6,8,11	5,6,11	5,6,11	
7	5,7,8	7	7	
8	5,8,	5,6,7,8	5,8	III
11	5,6,11	2,5,6,11	5,6,11	III

Table 4.6 Level partitions- IV iteration for barrier

Elements	Reachability Set	Antecedent Set	Intersection Set	Levels
1	1,6	1	1	
2	2	2	2	IV
6	6	6	6	IV
7	7	7	7	IV

Table 4.7 Level partitions- V iteration for barrier

Elements	Reachability Set	Antecedent Set	Intersection Set	Levels
1	1	1	1	V

Table 4.8 Level partitions final table for barrier

Elements	Reachability Set	Antecedent Set	Intersection Set	Levels
1	1,3,10	1,9	1	V
2	2,4,5,9,10,11	2	2	IV
3	3	1,3,4,5,6,10	3	I
4	3,4,6,7,9	2,4,5,6,7,11	4,6,7	II
5	3,4,5,6,8,9,10,11	2,5,6,7,8,9,11	5,6,8,9,11	III
6	3,4,5,6,8,9,10,11	4,5,6,11	4,5,6,11	IV
7	4,5,7,8,9	4,7	4,7	IV
8	5,8,10	5,6,7,8	5,8	III
9	1,5,9	2,4,5,6,7,9,11	5,9	I
10	3,10	1,2,5,6,8,10,11	10	II
11	4,5,6,9,10,11	2,5,6,11	5,6,11	III

4.2.4 *Developing conical matrix*

For developing a conical matrix (in Table 4.9) the variables are clustered in the same level across row and column of final reachability matrix. The conical matrix is developed for hierarchical understanding of ISM and the barriers are arranged in an order they were obtained in the table 4.8.

Table 4.9 Conical Matrix for barriers

Elements	3	9	4	10	5	8	11	2	6	7	1
3. Engineering Education	1	0	0	0	0	0	0	0	0	0	0
9. Fear of Failure	0	1	0	0	1	0	0	0	0	0	0
4. Absence of Industrial Controller	1	1	1	0	0	0	0	0	1	1	0
10. New Approach Required	1	0	0	1	0	0	0	0	0	0	0
5. High Complexity	1	1	1	1	1	1	1	0	1	0	0
8. Afraid of Complex Terminologies	0	0	0	1	1	1	0	0	0	0	0
11. Commercial Platform	0	1	1	1	1	0	1	0	1	0	0
2. Scalability	0	1	1	1	1	0	1	1	0	0	0
6. Lack of Awareness	1	1	1	1	1	1	1	0	1	0	0
7. Interoperability	0	1	1	0	1	1	0	0	0	1	0
1. Required Investment	1	1	0	1	0	0	1	0	1	0	1

4.2.5 *Development of ISM model*

The development of ISM model involves the ISM hierarchical level in which the barriers are placed. Level-I of ISM model is placed at the top and level-V is at the bottom. Required investment (1) coming in the level V and having the highest driving power placed at the lowest level of ISM model similarly barrier scalability (2) and interoperability (7) and lack of awareness (6) are kept above required investment i.e. is they comes under level IV of the developed ISM model, on moving further engineering education (3) and fear of failure (9) coming under level I and having high dependence power are placed at the top of the ISM model and accordingly whole ISM model has been developed in figure 4.2.

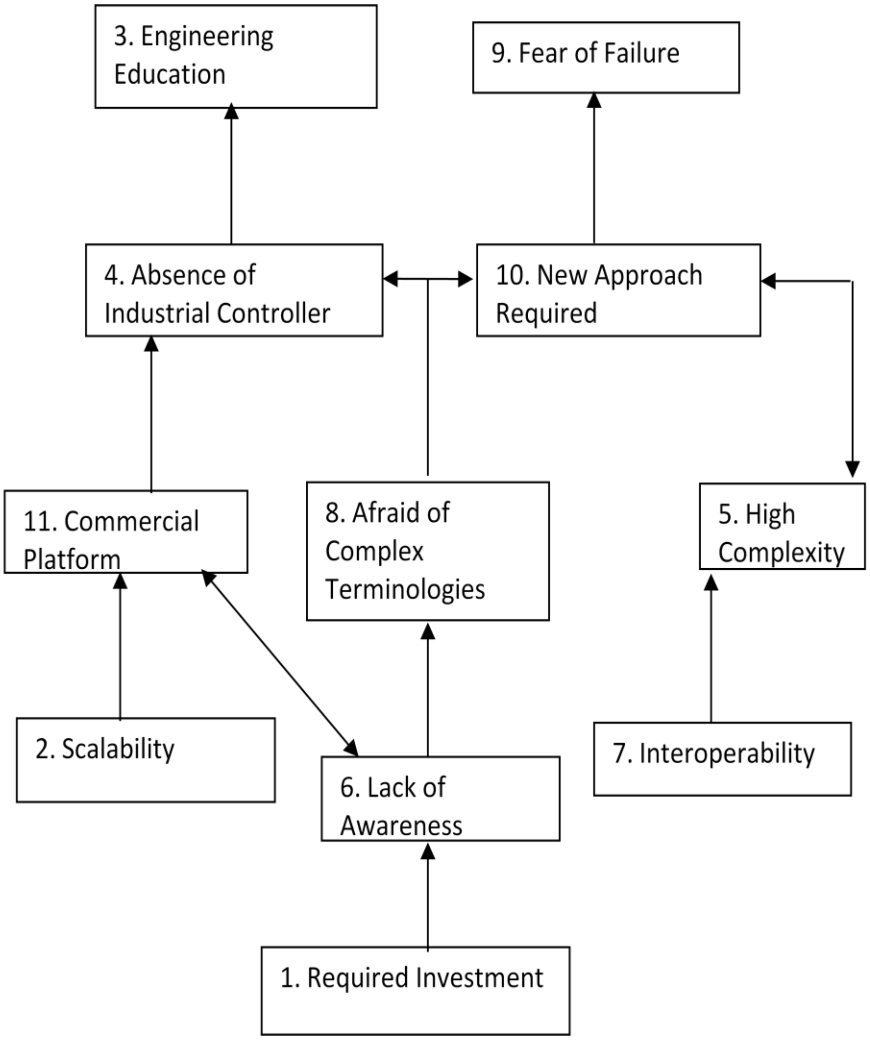

Figure 4.2 ISM Model for barrier

4.3 MICMAC analysis

The purpose of MICMAC analysis Mandal and Deshmukh (1994) in this research is to analyse the barriers of agent technology according to their driving and dependence power in considered manufacturing system. The barriers are classified in four categories based on their driving power and dependence power.

I. *Autonomous barriers:* These have weak driving and weak dependence power. These barriers are relatively disconnected from the ISM implementation process. In this category of barriers (afraid of complex terminologies) occurred.

II. *Dependent barriers:* It consists of dependent barriers that have weak driving power and strong dependence. In this category of barriers, three barriers (i.e. engineering education, new approach required and fear of failure) are placed.

III. *Linkage barriers:* This category of barriers includes strong driving power as well as strong dependence power. Four barriers (i.e. high complexity and absence of industrial control, lack of awareness and commercial platforms) are found in this category.

IV. *Independent barriers:* These types of barriers have strong driving power and weak dependence power. These are generally called as ‘key barriers’. Three barriers (i.e. interoperability, scalability and required investment) are found in this type of drivers.

After doing MICMAC analysis the driving power-dependence power diagram is drawn in Figure 4.3. This diagram is divided in to four categories. First category includes ‘autonomous barriers’, second contains ‘dependent barriers’, third comprises of ‘linkage barriers’ and ‘independent barriers’ are in fourth category. Also a driving-dependence power of barriers are calculated in the Table 4.10. The dependence power of barriers is defined by summing up of number of ones in the column likewise the driving power is obtained by adding the number of ones in the row. Moving ahead rank of driving power and dependence power is obtained of barriers having maximum sum in the rows and column accordingly.

Table 4.10 Driving power and dependence power for barrier

Elements	1	2	3	4	5	6	7	8	9	10	11	Diving Power	Rank
1. Required Investment	1	0	1	0	0	1	0	0	1	1	1	6	II
2. Scalability	0	1	0	1	1	0	0	0	1	1	1	6	II
3. Engineering Education	0	0	1	0	0	0	0	0	0	0	0	1	VI
4. Absense of Industrial Controller	0	0	1	1	0	1	1	0	1	0	0	5	III
5. High Complexity	0	0	1	1	1	1	0	1	1	1	1	8	I
6. Lack of Awareness	0	0	1	1	1	1	0	1	1	1	1	8	I
7. Interoperability	0	0	0	1	1	0	1	1	1	0	0	5	III
8. Afraid of Complex Terminologies	0	0	0	0	1	0	0	1	0	1	0	3	IV
9. Fear of Failure	0	0	0	0	1	0	0	0	1	0	0	2	V
10. New Approach Required	0	0	1	0	0	0	0	0	0	1	0	2	V
11. Commercial Platform	0	0	0	1	1	1	0	0	1	1	1	6	II
Dependencer Power	1	1	6	6	7	5	2	4	8	7	5		
Rank	VII	VII	III	III	II	IV	VI	V	I	II	IV		

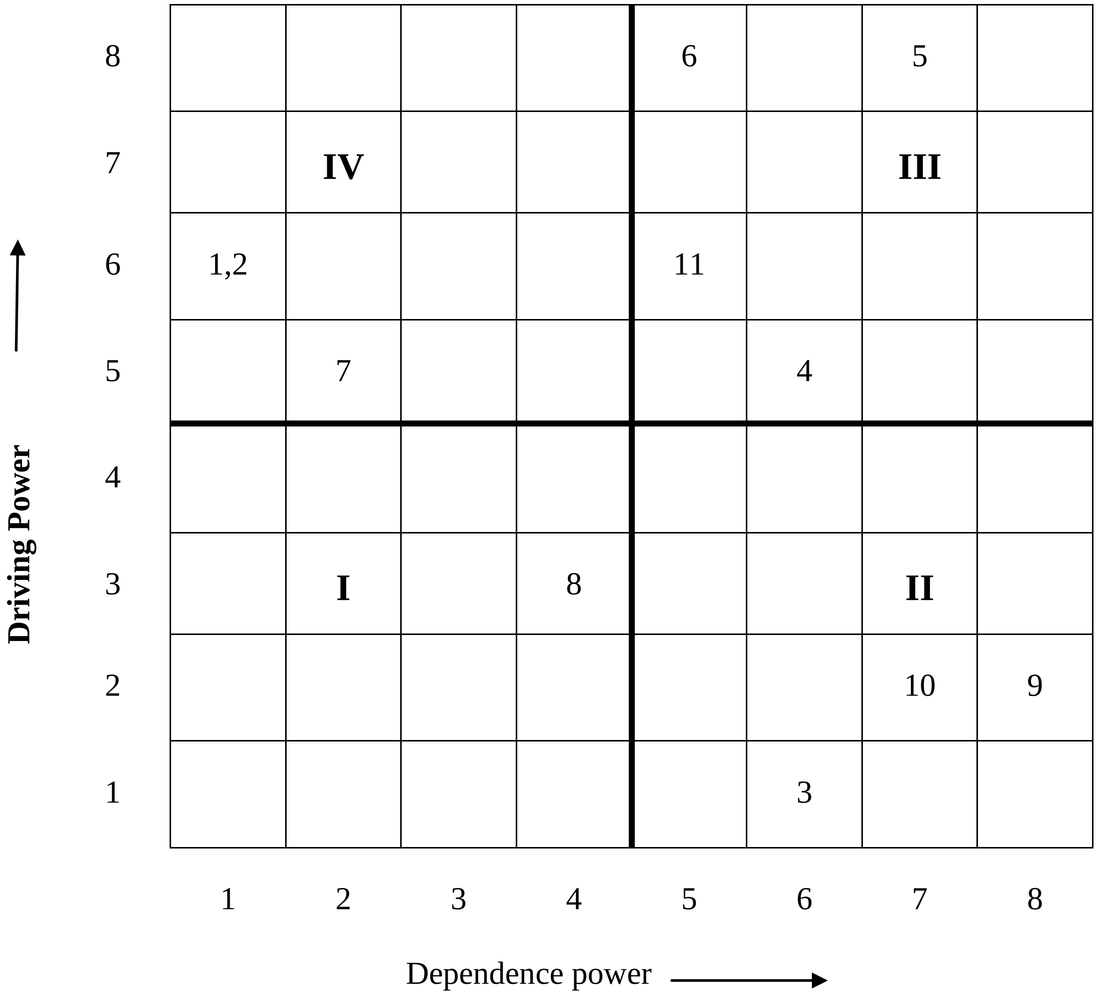

Figure 4.3 Driving power-dependence power diagram for barriers

4.4 Results and discussions

Agent technology and its implementation is one of the major discussed topic of today's manufacturing system and the most important thing is the barriers of agent technology that impede its implementation. It is very important to understand that how this barriers affect the implementation which barrier plays a crucial role in its restriction also it is important to look for the interdependency of one barrier on the other and how this barrier are interrelated.

The main objective of this study is to identify and define inter-relationships among all selected barriers of agent technology and further to analyze drive and dependence power of those barriers for successful AT implementation in a manufacturing system. To achieve these goals, ISM methodology has been deployed in order to understand the relationships among barriers completely so that the management of the manufacturing firm may give more stress on those barriers which are more influential for AT implementation. It will help to deal uncertainty in the manufacturing system environment which improves its flexibility and simultaneously customer satisfaction will also be achieved.

In this study ISM-MICMAC approach is used since binary relationships among selected barriers are being done by ISM while MICMAC approach describes sensitive analysis of driving and dependence behavior of barriers. It has been observed from ISM model (Figure 4.2) that the engineering education and fear of failure are at the first (Top) level of ISM model. The engineering education is a barrier which requires a different way of learning and understanding it requires. We are limited with our engineering course and thus the machine learning and artificial intelligence being not a part of our syllabus plays a major hindrance in the implementation of agent technology in the manufacturing system. Whereas fear of failure is always involved with implementation of new manufacturing system and when the cost involved is huge there is always a fear of failure. Hence lack of these barrier leads to the foundation that is a new approach is required to dealt with the problem of implementation also if there are proper industrial controller available or being developed than this barrier may not be that much influential they are at level 2 while moving ahead in the ISM model at level 3 are "afraid of complex terminologies, commercial platform and complex system". Level 4 comprise of interoperability, scalability and lack of awareness and at level 5 there is required investment. The barriers in level 4 and level 5 are the most driving barrier they are the major barriers which an organization facing for the implementation of agent technology in their manufacturing system. Moving ahead we have also analyze the driving and dependence power of the barriers that affect the AT implementation in a manufacturing system by MICMAC analysis. In MICMAC analysis, barriers are classified into four categories (Figure 4.3). The driving-dependence power diagram (Figure 4.3) shows that afraid of complex terminologies are found in the category of autonomous barriers. The engineering education, new approach required and fear of failure are weak barriers but strong dependent on other barriers (Figure 4.3- category II). These barriers are considered as important because these are shown in top level of ISM model. These barriers are more dependent on other barriers (Figure 4.3-category IV). Four barriers i.e. high complexity, absence of industrial controller, commercial platform and lack of awareness are strong barriers and strong dependent on others (Figure 4.3-category III). Figure 4.3-category IV indicates the interoperability scalability and required investment are strong driving barriers and weak dependent on others. These barriers are crucial and are of most importance. As they drive all the other barriers. Elimination of these barriers may lead to successful implementation of agent technology in a manufacturing system. It means that the management needs focus on these barriers more cautiously. It has been observed that these barriers help to attain other barriers which are at the top level of ISM model.

CHAPTER 5

CASE STUDY

5.1 Case study description

The case study is about the implementation of agent technology in manufacturing system of three different companies all the three companies are national companies. The survey has been done on the plants at northern and central India. Company ‘x’ deals with the robots and works on artificial intelligence whereas company ‘y’ is a pump manufacturing company with the global sale of pump and is situated in the central India and company ‘z’ is a bearing manufacturing company situated in northern India. A detailed survey is done on all the above mentioned companies. A questionnaire is prepared and is being filled up by the employees and top management of the companies. All the details have been explained and the factors are considered while preparing the questionnaire. With the help of that a better understanding has been developed about how the agent technology is being implemented in the current scenario and how it can been improved what more steps can be taken for the better implementation and how the different companies differ in their manufacturing style and how their manufacturing approach affects their profit and future of the companies. With these the companies also got to know where they are lacking and how their system can be improved. Due to globalization it is now a need to be competitive and to withstand not only the local challenge but a challenge from other parts of the world too. To face such a competition there is a need for moving towards a better and more optimum way of manufacturing process. But looking at the present scenario where a multiple agent works together. There is a need of different manufacturing system which can be self sufficient and is able to understand the need and importance of present scenario. The present work has been appreciated by the firms and shown a great interest and enthusiasm for the present survey work. All the three companies are then compared with the help of multi criterion decision making technique that is the grey approach. A grey possibility index is obtained and the companies are compared.

5.2 Brief review of Grey based decision making approach

Grey approach is amongst the most widely used MCDM technique. Some studies where MCDM problems have been solved by grey theory are as follows: Li and Liu (2008) proposed an effective tool to study an economic system under uncertain circumstances by grey matrix and grey input-output analysis. Tseng et al. (2012) presented an empirical study of green innovation drivers in the domains of environmental management using a grey relational analysis with entropy weight. Wang et al. (2012) evaluated the hazards of an urban rail transit dynamic operating systems and conducted quantitative risk analysis in the operation process using grey system theory. Yang and Chen (2006) proposed an integrated model of analytical hierarchy process and grey relational analysis for supplier selection MCDM problem in an outsourcing manufacturing organization. Mishra et al. (2013) developed a grey-based and fuzzy TOPSIS MCDM approach to select the most suitable agile system for implementing mass customization strategies. Goyal and Grover (2012) proposed a fuzzy-grey relational analysis MCDM method for the selection of proper advanced manufacturing system. Huang et al. (2011) described a real estate demand analyzing model using grey system theory and multivariate regression analysis. Tseng and Chiu (2012) suggested an evaluation strategy for green innovation practices in world's largest printed circuit board manufacturing firm under uncertainties using integrated model of grey theory, entropy weight and analytical network process

5.3 Grey Methodology

Grey approach (Deng, 1989) is one of the methods used for studying uncertainty and this approach is based on degree of information known. This approach is appropriate for solving the MCDM problem in an uncertain environment (Li et al., 2007). Assuming A = {A_1, A_2, ..., A_m} is a set of m possible alternatives while C = {C_1,C_2, ..., C_n} is a set of n criteria, which are additively independent. W = {w_1, w_2, . . . ,w_n} is the vector of criteria weights. This research work considers the criteria weights and ratings of manufacturing systems as linguistic variables (Li et al., 2007).

In this section a MCDM technique that is grey approach is used to compare three manufacturing firms on the basis of most influential critical drivers and barriers that are obtained from the driving-dependence diagram discussed in the MICMAC analysis of drivers and barriers respectively. As it is observed from the figure 3.3 that the ambient intelligence and complex system are amongst the most dependent drivers whereas web services and service oriented computing, self system and autonomic computing and semantic web are the most influential drivers and having maximum driving power. The barriers of agent technology which are having the most the most driving power are required investment, scalability and interoperability whereas the barriers having most dependent power are the engineering education, new approach required and fear of failure as obtained from the figure 4.3. Thus this 11 criteria are selected from the 19 drivers and barriers identified. The linkage and autonomous drivers and barriers are not considered in the evaluation criteria as they are not that much influential compared to dependent and independent variables. The linkage drivers and barriers are those which is having weak driving as well as weak dependence power on the other hand the autonomous drivers and barriers are one which are having high driving as well as high dependence power. Thus both are not considered in the evaluation of implementation of agent technology in three different manufacturing firms. The lists of all the selected 11 evalution criteria are shown in the table 5.1.

Table 5.1 Evaluation criteria for agent technology

Evaluation Criteria	**Code**
Semantic web	C1
Web services and service oreinted computing	C2
Interoperability	C3
Required investment	C4
Ambeint intelligence	C5
Complex system	C6
Scalability	C7
Fear of failure	C8
New approach required	C9
Engineering education	C10
Self system and autnomic computing	C11

5.3.1 Setting criteria weights and criteria rating

Scale	Weight
Very low (VL)	[0.0, 0.1]
Medium low (ML)	[0.1, 0.3]
Low (L)	[0.3, 0.4]
Medium (M)	[0.4, 0.5]
High (H)	[0.5, 0.7]
Medium high (MH)	[0.7, 0.9]
Very high (VH)	[0.9, 1.0]

Scale	Weight
Very poor (VP)	[0, 1]
Medium poor (MP)	[1, 3]
Poor (P)	[3, 4]
Fair (F)	[4, 5]
Good (G)	[5, 7]
Medium good (MG)	[7, 9]
Very good (VG)	[9, 10]

5.3.2 Calculation of criteria weights

A group of three DMs as mentioned earlier gave responses for selection of criteria, criteria weights, rating of each criterion with respect to eight factors in terms of grey numbers.

In this step, factor weights are identified by a group of decision makers. If the group has k persons then the criterion weight is calculated as

$$\otimes W = \frac{1}{k}[\otimes W_j^1 + \otimes W_j^2 + \ldots\ldots\ldots + \otimes W_j^k] \quad \text{----------------------------} \quad (1)$$

Where $\otimes W_j^k$ $(j = 1,2,3 \ldots . n)$ is the criterion weight of k^th DM and can be described by grey number$\otimes W_j^k = [\,\underline{W_j}^k, \overline{W_j}^k\,]$. The operator '⊗' denotes grey number and $\underline{W_j}^k$ and $\overline{W_j}^k$ describe lower and upper value of the j^th criterion weight respectively.

The grey values for factor weights can be obtained from the group of three decision makers DM1, DM2 and DM3 according to equation (1). Thus the weight for criterion factor C1 is ⊗Wj = [(0.7+0.9+0.7)/3, (0.9+1.0+0.9)/3] = [0.766, 0.933]. Similarly, the weight values were computed for other criteria and the weights for C1 to C11 are shown in table 5.2.

Table 5.2 Criteria weight for grey approach

Criteria weights

Criteria	**DM1**	**DM2**	**DM3**	**#Wj (weight)**
C1	[0.7,0.9]	[0.9,1.0]	[0.7,0.9]	[0.766,0.933]
C2	[0.4,0.5]	[0.7,0.9]	[0.5,0.7]	[0.533,0.7]
C3	[0.7,0.9]	[0.9,1.0]	[0.7,0.9]	[0.766,0.933]
C4	[0.4,0.5]	[0.5,0.7]	[0.9,1.0]	[0.60,0.733]
C5	[0.1,0.3]	[0.5,0.7]	[0.9,1.0]	[0.50,0.666]
C6	[0.9,1.0]	[0.9,1.0]	[0.5,0.7]	[0.766,0.90]
C7	[0.9,1.0]	[0.5,0.7]	[0.7,0.9]	[0.70,0.866]
C8	[0.3,0.4]	[0.4,0.5]	[0.9,1.0]	[0.533,0.633]
C9	[0.3,0.5]	[0.5,0.7]	[0.1,0.3]	[0.30,0.50]
C10	[0.5,0.7]	[0.5,0.7]	[0.7,0.9]	[0.566,0.766]
C11	[0.9,1.0]	[0.5,0.7]	[0.7,0.9]	[0.70,0.866]

5.3.3 Calculation of criteria ratings

Criterion rating values are calculated using linguistic variables as,

$$\otimes G_{ij} = \frac{1}{k}\left[\otimes G_{ij}^{1} + \otimes G_{ij}^{2} + \dots\dots + \otimes G_{ij}^{k}\right] \qquad \text{------------------------------} \qquad (2)$$

Where $\otimes G_{ij}^{k}$ (i=1, 2... m; j=1, 2... n) is the criterion rating value of kth DM and can be described by grey number$\otimes G_{ij}^{k} = [\underline{G}_{ij}^{k}, \overline{G}_{ij}^{k}]$.

Obtain factor rating values for each of the three manufacturing systems from the DMs. For example, as per equation (2) the criterion rating value for manufacturing firm1 or first company with respect to factor C1 is ⊗Gij = [(7+7+9)/3, (9+9+10)/3] = [7.66, 9.33].

In a similar manner, the factor rating values for three manufacturing firms with respect to C1 – C11 are shown in Table 5.3 on the next page.

5.3.4 Establishing the grey decision matrix

In this step grey decision matrix is established.

$$D = \begin{bmatrix} \otimes G_{11} & \otimes G_{12} & \cdots & \otimes G_{1n} \\ \otimes G_{21} & \otimes G_{22} & \dots & \otimes G_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \otimes G_{m1} & \otimes G_{m2} & \dots & \otimes G_{mn} \end{bmatrix} \qquad \text{----------------------------} \qquad (3)$$

Establish the grey decision matrix according to equation(3), using criterion rating grey values ⊗**Gij** for all three manufacturing firms with respect to C1 - C8 form Table 5.4.

Table 5.4 Grey decision matrix (D)

Alter ntives	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11
M1	[7.66, 9.33]	[5.33, 7]	[7.66, 9]	[5, 6.66]	[6.33, 8.33]	[7.66, 9.33]	[7.66, 9.33]	[6.33, 8.33]	[7, 8.66]	[6.33, 8.33]	[7.66, 9.33]
M2	[4.33, 5.66]	[7.00, 8.66]	[5.66, 7.66]	[8.33, 9.66]	[4, 5.33]	[5.66, 6.66]	[5.33, 7]	[3, 4.33]	[5.33, 7]	[7.66, 9.33]	[4.33, 5.66]
M3	[4, 5.33]	[1.66, 3]	[4.33, 5.66]	[4.66, 6.33]	[5.66, 7.66]	[4.66, 6]	[3.66, 5]	[1.66, 3]	[3.66, 5]	[4.33, 5.66]	[4.33, 6.33]

Table 5.3 Criteria ratings for three manufacturing systems

Criteria	**Manufacturing Firm**	**DM1**	**DM2**	**DM3**	**#Gij (rating)**
C1	**M1**	[7,9]	[7,9]	[9,10]	[7.66,9.33]
	M2	[4,5]	[4,5]	[5,7]	[4.33, 5.66]
	M3	[3,4]	[5,7]	[4,5]	[4, 5.33]
C2	**M1**	[4,5]	[5,7]	[7,9]	[5.33,7]
	M2	[5,7]	[7,9]	[9,10]	[7,8.66]
	M3	[1,3]	[0,1]	[4,5]	[1.66,3]
C3	**M1**	[9,10]	[9,10]	[5,7]	[7.66,9]
	M2	[5,7]	[5,7]	[7,9]	[5.66,7.66]
	M3	[4,5]	[5,7]	[4,5]	[4.33, 5.66]
C4	**M1**	[7,9]	[3,4]	[5,7]	[5,6.66]
	M2	[9,10]	[9,10]	[7,9]	[8.33,9.66]
	M3	[4,5]	[5,7]	[5,7]	[4.66,6.33]
C5	**M1**	[5,7]	[7,9]	[7,9]	[6.33,8.33]
	M2	[3,4]	[5,7]	[4,5]	[4,5.33]
	M3	[7,9]	[5,7]	[5,7]	[5.66,7.66]
C6	**M1**	[7,9]	[9,10]	[7,9]	[7.66,9.33]
	M2	[4,5]	[4,5]	[9,10]	[5.66,6.66]
	M3	[3,4]	[7,9]	[4,5]	[4.66,6]
C7	**M1**	[7,9]	[7,9]	[9,10]	[7.66,9.33]
	M2	[7,9]	[4,5]	[5,7]	[5.33,7]
	M3	[3,4]	[5,7]	[3,4]	[3.66,5]
C8	**M1**	[7,9]	[5,7]	[7,9]	[6.33,8.33]
	M2	[1,3]	[4,5]	[4,5]	[3,4.33]
	M3	[0,1]	[4,5]	[1,3]	[1.66,3]
C9	**M1**	[7,9]	[5,7]	[9,10]	[7,8.66]
	M2	[7,9]	[4,5]	[5,7]	[5.33,7]
	M3	[3,4]	[5,7]	[3,4]	[3.66,5]
C10	**M1**	[7,9]	[5,7]	[7,9]	[6.33,8.33]
	M2	[9,10]	[7,9]	[7,9]	[7.66,9.33]
	M3	[4,5]	[5,7]	[4,5]	[4.33, 5.66]
C11	**M1**	[7,9]	[7,9]	[9,10]	[7.66,9.33]
	M3	[4,5]	[4,5]	[5,7]	[4.33,5.66]
	M3	[5,7]	[5,7]	[4,5]	[4.33,6.33]

Normalize the grey decision matrix.

$$D^{*} = \begin{bmatrix} \otimes G_{11}^{\star} & \otimes G_{12}^{\star} & \cdots & \otimes G_{1n}^{\star} \\ \otimes G_{21}^{\star} & \otimes G_{22}^{\star} & \dots & \otimes G_{2n}^{\star} \\ \vdots & \vdots & \ddots & \vdots \\ \otimes G_{m1}^{\star} & \otimes G_{m2}^{\star} & \dots & \otimes G_{mn}^{\star} \end{bmatrix} \tag{4}$$

For a benefit criteria, $\otimes G_{ij}^{\star}$ is expressed as,

$$\otimes G_{ij}^{\star} = \left[\frac{\underline{G}_{ij}}{G_j^{max}}, \frac{\overline{G}_{ij}}{G_j^{max}} \right] \tag{5}$$

Where $G_j^{max} = max_1 \leq i \leq m \, \overline{G}_{ij}$

For a cost criteria is expressed as, $\otimes G_{ij}^{\star}$ is expressed as,

$$\otimes G_{ij}^{\star} = \left[\frac{G_j^{min}}{\overline{G}_{ij}}, \frac{G_j^{min}}{\underline{G}_{ij}} \right] \tag{6}$$

Where $G_j^{min} = min_1 \leq i \leq m \, \underline{G}_{ij}$

The normalization method mentioned above is to preserve the property that the ranges of the normalized grey number belong to [0, 1].

Normalize the grey decision matrix using benefit criterion for LMS w.r.t. C1 is D^{*} = [5.25/8.75, 7.25/8.75] = [0.6, 0.83] and similarly normalised grey values for three manufacturing system alternatives with respect to C1 – C11 as in Table 8

Table 5.5 Grey normalized decision matrix (D)*

Alternatives	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11
M1	[0.82, 1]	[0.61, 0.80]	[0.85, 1]	[0.51, 0.68]	[0.75, 1]	[0.82, 1]	[0.82, 1]	[0.75, 1]	[0.80, 1]	[0.67, 0.89]	[0.82, 1]
M2	[0.46, 0.60]	[0.80, 1]	[0.65, 0.88]	[0.86, 1]	[0.48, 0.63]	[0.60, 0.71]	[0.57, 0.75]	[0.36, 0.51]	[0.61, 0.80]	[0.82, 1]	[0.46, 0.60]
M3	[0.42, 0.57]	[0.19, 0.34]	[0.5,0.65]	[0.48, 0.65]	[0.67, 0.91]	[0.49, 0.64]	[0.39, 0.53]	[0.19, 0.36]	[0.42, 0.57]	[0.46, 0.60]	[0.46, 0.67]

5.3.5 Weighted normalized matrix formation

In this step, considering the importance of each criteria, establish the weighted normalized grey decision matrix.

$$D^{**} = \begin{bmatrix} \otimes V_{11} & \otimes V_{12} & \cdots & \otimes V_{1n} \\ \otimes V_{21} & \otimes V_{22} & \dots & \otimes V_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \otimes V_{m1} & \otimes V_{m2} & \dots & \otimes V_{mn} \end{bmatrix} \qquad \text{---} \qquad (7)$$

Where $\otimes V_{ij} = \otimes G_{ij}^{\star} \times \otimes W_j$

After normalisation, the grey decision matrix is weighted to obtain the weighted normalised grey decision matrix which is the product of normalised grey decision values (⊗Gij) and criteria weight values (⊗Wj) using eqn (7). D^{**} = [0.82×0.766, 1×0.93] = [0.62, 0.93]. Similarly, other grey weighted normalized values are obtained and are shown in Table 5.6.

Table 5.6 Grey weighted normalized decision matrix (D) **

Alter-natives	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11
M1	[0.62, 0.93]	[0.32, 0.56]	[0.65, 0.93]	[0.30, 0.49]	[0.37, 0.66]	[0.62, 0.90]	[0.57, 0.86]	[0.39, 0.63]	[0.24, 0.50]	[0.37, 0.68]	[0.57, 0.86]
M2	[0.35, 0.55]	[0.42, 0.70]	[0.49, 0.82]	[0.51, 0.73]	[0.24, 0.41]	[0.45, 0.63]	[0.39, 0.63]	[0.19, 0.32]	[0.18, 0.40]	[0.46, 0.76]	[0.32, 0.45]
M3	[0.31, 0.53]	[0.10,0.23]	[0.38, 0.6]	[0.28, 0.47]	[0.33, 0.60]	[0.37, 0.57]	[0.27, 0.45]	[0.10, 0.22]	[0.12, 0.28]	[0.26, 0.45]	[0.32, 0.58]

Now the next step is to calculate the grey possibility degree from ideal referential alternatives and the compared alternatives.

5.3.6 Identifying ideal referential alternatives

Make the ideal alternative as a referential alternative. For m possible alternatives set A= {A1, A2,....,Am}, the ideal referential alternative $A^{max} = \{\otimes G_1^{max}, \otimes G_2^{max}, \ldots\ldots\ldots, \otimes G_n^{max}\}$ can be obtained by

$A^{max} = \{[\max_{1\le i\le m} \underline{V}_{i1}, \max_{1\le i\le m} \overline{V}_{i1}], [\max_{1\le i\le m} \underline{V}_{i2}, \max_{1\le i\le m} \overline{V}_{i2}], \ldots\ldots, [\max_{1\le i\le m} \underline{V}_{in}, \max_{1\le i\le m} \overline{V}_{in}]\}$ ----- (8)

Set ideal alternative manufacturing system as a referential manufacturing system according to equation (8) which is given as below:

A^{max}={[0.62,0.93],[0.42,0.7],[0.65,0.93],[0.51,0.73],[0.37,0.66],[0.62,.9],[0.57,0.86], [0.39,0.63],[0.24,0.50],[0.46,0.76],[0.57,0.86]}.

The grey values in A^{max} are the maximum value of each criterion in grey weighted normalized decision matrix.

5.3.7 Calculation of grey possibility degree

Calculate the grey possibility degree between compared alternatives set A= {A_1, A_2, ...,A_m } and ideal referential alternative A^{max} .

$P\{A_i \le A^{max}\} = \frac{1}{n}\sum_{j=1}^{n} P\{\otimes V_{ij} \le \otimes G_j^{max}\}$. ------------------------------- (9)

Grey possibility degrees for three manufacturing systems, according to equation no. (9), are given below: (Shi et.al.25)

$P(A_1 \le A^{max}) = \frac{1}{11}[P(\otimes V_{11} \le \otimes G_1^{max}) + P(\otimes V_{12} \le \otimes G_2^{max}) + P(\otimes V_{13} \le \otimes G_3^{max}) + P(\otimes V_{14} \le \otimes G_4^{max}) + P(\otimes V_{15} \le \otimes G_5^{max}) + P(\otimes V_{16} \le \otimes G_6^{max}) + P(\otimes V_{17} \le \otimes G_7^{max}) + P(\otimes V_{18} \le \otimes G_8^{max}) + P(\otimes V_{19} \le \otimes G_9^{max}) + P(\otimes V_{110} \le \otimes G_{10}^{max}) + P(\otimes V_{111} \le \otimes G_{11}^{max})]$

$P(\otimes V_{11} = \otimes G_1^{max})$, and hence $P(\otimes V_{11} \le \otimes G_1^{max})$ = 0.5

Here $\otimes V_{12} \le \otimes G_2^{max}$, [max(0, L* - max (0, $\otimes \bar{V}_{12}$- $\underline{G}_2^{max}$))/ L*]

Where $\otimes V_{12}$ = [0.32, 0.56], $\otimes G_2^{max}$ = [0.42, 0.7]

L* = L($\otimes V_{12}$) + L($\otimes G_2^{max}$) = ($\bar{V}_{12} - \underline{V}_{12}$) + ($\overline{G}_2^{max} - \underline{G}_2^{max}$) = (0.56– 0.32) + (0.7 – 0.42)= 0.52

$P(\otimes V_{12} \le \otimes G_2^{max})$ = [max(0, 0.52-0.14)/0.52] = 0.73

Similarly $P(\otimes V_{13} \le \otimes G_3^{max})$= 0.5,

$P(\otimes V_{14} \le \otimes G_4^{max})$= 0.5,

Here $\otimes V_{14} \le \otimes G_4^{max}$, [max(0, L* - max (0, $\otimes \bar{V}_{14}$- $\underline{G}_4^{max}$))/ L*]

Where $\otimes V_{14}$ = [0.3, 0.49], $\otimes G_4^{max}$ = [0.51, 0.73]

L* = L($\otimes V_{14}$) + L($\otimes G_4^{max}$) = ($\overline{V}_{14} - \underline{V}_{14}$) + ($\overline{G}_4^{max} - \underline{G}_4^{max}$) = (0.49–0.3) + (0.73 – 0.51)= 0.41

$P(\otimes V_{14} \leq \otimes G_4^{max})$ = [max(0, 0.41-)/0.41] = 1

Similarly,

$P(\otimes V_{15} \leq \otimes G_5^{max}) = 0.5$, $P(\otimes V_{16} \leq \otimes G_6^{max}) = 0.5$, $P(\otimes V_{17} \leq \otimes G_7^{max}) = 0.5$, $P(\otimes V_{18} \leq \otimes G_8^{max})$=0.5 $P(\otimes V_{19} \leq \otimes G_9^{max})$=0.5 $P(\otimes V_{110} \leq \otimes G_{10}^{max}) = 0.65$, $P(\otimes V_{111} \leq \otimes G_{11}^{max})$=0.5

P($A_1 \leq A^{max}$) =

$\frac{1}{11}(0.5 + 0.73 + 0.5 + 1 + 0.5 + 0.5 + 0.5 + 0.5 + 0.5 + 0.65 + 0.5)$ =0.58

Similarly grey possibility degrees for other alternative manufacturing systems can be calculated which are shown in Table 5.7.

Table 5.7 Grey possibility degree

Alternatives	Grey possibility degree
M1	**0.58**
M2	**0.78**
M3	**0.94**

5.3.8 Comparison of alternative and ideal grey possibility degree

Rank the order of alternatives based on $P\{A_i \leq A^{max}\}$ comparison. If A_i value is smaller, the ranking order of A_i is better than other A_i values.

Three manufacturing firms are prioritized on the basis of grey possibility degrees. The alternative which has lowest grey possibility value (A_i) will be the best alternative and which has highest grey possibility value will be the worst alternative. The physical significance of lower and higher A_i values is the smaller and larger differences from ideal grey possibility value respectively. The ranking order as follows: x > y > z.

5.4 Results and discussion

The criteria C1 semantic web and C3 interoperability has the highest weight as observed in the table 5.2. Thus these are the two evaluation criteria which are of major importance and are considered to play an essential role in implementation of agent technology. Also the firms selected and other organizations can understand the importance of each evaluation criteria and may work on all the factors for better implementation of agent technology.

Also it can be observed that the company “y” is better in criteria C2, C4 and C10 that is the company “y” has better web services and service oriented computing also they did not find engineering education as a barrier and required investment is also considered to be more where the company “x” lacks in this three criteria rest it is better in implementation of agent technology as compared to company “y” apart from this company “z” with least automation of agent technology leads company “y” in the criteria of ambient intelligence apart from this company “y” is better in all the other aspects than company “z”.

The grey possibility degrees for three manufacturing firms x, y and z are calculated as 0.58, 0.78 and 0.94 respectively. These values represent the deviation from ideal alternative values. The smaller grey possibility value of an alternative represents low deviation from ideal alternative value and hence considered to be the most suitable alternative among others. On the other hand, higher grey possibility value represents high deviation and hence it is considered to be the least suitable alternative. In this problem grey possibility degree for firm x is lowest and for firm z it is highest. So it can be concluded that firm x is the most suitable and the implementation of agent technology is more or we can say that agent technology is implemented in better way in this manufacturing system. Thus the comparative order can be given as: x > y > z.

CHAPTER 6

CONCLUSION

Conclusion

The drivers and barriers of agent technology are understood and how they are going to impact the manufacturing system has been explained in this thesis work. It has been found that agent technology is the future of manufacturing system and thus this research work plays a vital role for any firm which is interested in the implementation of agent technology. A case study showing the comparison of three manufacturing firms is also presented. The three manufacturing firms are compared on the basis of implementation of agent technology. The most influential drivers and barriers are selected as evaluation criteria for their comparison.

First the drivers and barriers are identified and then with the help of ISM technique they are evaluated that how they affect the implementation of agent technology. It has been observed that the web services and service oriented computing is amongst the major driver and for the implementation its plays an important role for a firm this driver is must as it drives other enabler also a firm should focus on other enablers for better implementation of agent technology. Coming on to the barriers in this research work 11 barriers are identified and there interdependency is found out by ISM technique. Barriers such as required investment, interoperability and scalability are the key barriers and are the major hindrance in the implementation of agent technology thus they are of major concern and should be eradicated from the manufacturing system. The enablers and barriers are also analysed on the basis of their driving power and dependence power with the aid of Micmac analysis. The drivers and barriers are bifurcated in four different regions on a Micmac graph in order to make a better understanding of their interdependency and importance. Moving forward from the identified drivers and barriers most influential drivers and barriers are selected through the MICMAC analysis. Out of 19 drivers and barriers 11 are selected as evaluation criteria for three different manufacturing firms. It is being investigated through the case study that all the company experts suggests that the semantic web, interoperability and lack of awareness are most amongst the most important evaluation criteria for the development and implementation of the agent technology in any firm thus this three evaluation criteria should be well maintained. The selected three manufacturing firms are evaluated on the basis of their implementation of agent technology by the aid of a MCDM technique that is Grey approach and it is being found that the company x is having the least grey possibility index and thus it is the best company amongst the three companies selected. If company "y" and "z" works on the critical barriers discussed above in the thesis, i.e. scalability and interoperability, and the organization should cope up with barriers discussed above. Also as the investment is the major barrier the organization should focus on the long term advantages of agent technology. Thus agent technology is better understood and may be implemented in a better way with the help of this thesis work for any organization looking for shift towards the agent technology once must go through the above work as it will be very beneficial and fruitful for the organization. The investigations performed over implementation of agent technology in manufacturing system would have been more clarified if its practical implications are observed also the validation of the qualification of experts are not taken into considerations. For better results and more sensitive analysis we can go with fuzzy Micmac in place of Micmac analysis.

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