Modeling of Enablers for Implementing ICT Enabled Wireless Control in Industry: an Integrated ISM and Fuzzy MICMAC Approach

Dr. Jayalakshmi.B
Professor
Instrumentation and Control Engineering Department
NSS College of Engineering
Palakkad, Kerala, India.
b_jayahari@yahoo.com
Haritha .H
Programmer Analyst
Cognizant Technology Solutions
Kochi , INDIA
parunandanam94@gmail.com
Abijith Maniyeri
MENS
University of Southern Queensland
Toowoomba, AUSTRALIA
legasy.a@gmail.com

Abstract

The incumbent trend in process industry is to deploy Information and communication technology (ICT) enabled wired process control systems. Distributed control system, Supervisory control and data acquisition systems with wireless open loop control systems are commonly used to facilitate the same. However, wireless closed loop control systems have not yet been introduced in the process industry. The major theme of this work is to model the enablers of implementing ICT enabled control system in the process industry based on their interrelationships. Interpretivestructural modeling (ISM) methodology is applied for the development of structural relationship among the enablers from a strategic perspective. Fuzzy MICMAC analysis is then carried out to categorize these factors based on their driving and dependence value. The paper is concluded with an action plan for enhancing high driving power elements and managerial implications.

Keywords
ICT;ISM, **Fuzzy MICMAC;Fuzzy ISM**.

1.Introduction

Current researchers and practitioners are extremely being fascinated by the adoption of ICT as it will be highly beneficial [1] to all fields of business. In continuation to this, the field of education has significantly improved due o he adoption of ICT. Recent trend in education is to implement different types of educational programs using ICT [2]. While peeping in to the world of literature, a plethora of research can be witnessed in internet based control systems accessing data wirelessly from a remotely located process. Monitoring and controlling of such systems are done by using Wireless and Internet communications technologies [3].
A wireless communication system has a number of advantages, not least the mobility of the devices within the environment. Adding in a communication device to the system or removing one from it without any disruption to the remainder of the system is cakewalk. Keeping apart the initial outlay on setting up the cell sites, the cost

of running and maintaining a radio based communications solution is minimal. These coupled with other factors prove the appeal for a radio communication system in the office environment. Being a public frequency network, wireless interface is extremely risky for official private information. As the number of users utilizing the same frequency increase, the rapidity and the feasibility of the wireless signals decline. The shortcomings of the aforesaid wireless network can be overcome to a great extent by using high speed point-to-point wireless networking and wireless backhaul. Point-to-point wireless networkinguses series topology instead of mesh, which increases the radial distance coverage and removes geographical barriers. This network, being an invisible one is not easily hindered and an alternate solution helps to restore the connectivity in the event of any interruption. Wireless backhaul is an economic connection, which can handle a huge amount of data uploading, and down loading in a blink of an eye and many new applications [4].

Only a few researches were being reported in emerging systematic design methods using this technology or in designing ICT enabled process control systems. Several open loop wireless control systems such as wireless transmitter and ICT enabled control valves are available in the process industry. Nevertheless, owing to security issues, industrialists have not dared to implement these innovative methods for a closed loop system till date even for a trial basis.Authors hope that by incorporating new security methods such as wired equivalent privacy 2 (WEP2),point-to-point wireless networkingand wireless backhaul in the network of ICT enabled process control system, the system can be effectively used in industry. In this research work, the authors make an attempt to analyze the possibility of implementing such a system in industry. The major objective of this paper is to analyze the inter relationships between the enablers of ICT enabled wireless process control system using Interpretive Structural Modeling (ISM).

2. Interpretive structural modeling (ISM) Methodology

The interrelationships among the various elements and their degree of associations can be effectively assessed by ISM. It is used to determine the most prominent knowledge sharing barriers that deserve serious consideration [5].Based on correlation, an overall configuration is hauling out from the complex set of variables [6; 7; 8 and 9].ISM is effectively used to determine the critical success factors of R&D Performance in Indian Manufacturing Firms [10].In order to frame the aims and objectives of this research work, enablers of ICT enabled process control systems are derived from a brainstorming session with about 15 experts from industry possessing in-depth knowledge and high potential in the field. These enablers have been interrelated using ISM. For this structural self-interaction matrix, initial reach ability matrix, final reach ability matrix and diagraph have been made and finally diagraph is converted to ISM to make it more transparent. An action plan for the study is prepared after observing the driving power-dependence graph.

2.1. Enablers of ICT enabled wireless control system

At the outset, by conducting face to face interaction and telephonic interviews with about 15 experts from leading process industries having thorough knowledge in the field and from literature survey, enablersof ICT enabled process control system were identified as having the following attributes:

1) They are free from the hassle of cables and are thus mobile
2) It can work efficiently under harsh conditions.
3) It can be deployed on a large scale.
4) Ease of maintenance.
5) Noise due to cabling faults such as earth faults can be reduced.
6) User friendly.
7) Time saving for installation and commissioning.
8) System will be more flexible.
9) Enhances overall efficiency.
10) Ideal for areas where network is scarce such as across river or mountain or rural area.
11) Can be accessed through a centralized monitor.

2.2 Formation of the Structural self-interaction matrix (SSIM) of enablers

SSIM reveals the direction of appropriate relationships among the components of enablers. The enablers are shown in column one and the same elements are arranged in reverse order in columns two to twelve. SSIM thus developed is shown in Table 1.

Table 1: Structural self-interaction matrix of enablers

Enablers	11	10	9	8	7	6	5	4	3	2	1
1	O	X	X	O	V	X	A	V	O	A	1
2	O	V	O	V	V	V	X	O	O	1	
3	O	O	A	X	X	A	A	X	1		
4	O	A	A	O	O	O	A	1			
5	V	V	O	O	V	V	1				
6	X	A	O	X	O	1					
7	X	O	O	A	1						
8	X	X	A	1							
9	O	O	1								
10	O	1									
11	1										

2.3Initial reach ability matrix (IRM) of enablers

In this step, SSIM has been converted into a matrix of binary elements named as IRM. In order to get it materialized, following rules are applied. 1)If the (imp) entry in the SSIM is V then substitute in the (I,j) entry in the reach ability matrix as 1 and (j,i) entry as 0.(2) If the (i,j) entry in the SSIM is A then substitute in the (i,j) entry in the reach ability matrix as 0 and (j,i) entry as 1.(3) If the (i,j) entry in the SSIM is X then substitute in the (i,j) entry in the reach ability matrix as 1 and (j,i) entry as 1.(4) If the (i,j) entry in the SSIM is O then substitute in the (i,j) entry in the reach ability matrix as 0 and (j,i) entry as 0. IRM thus developed is shown in Table 2.

Table 2: Initial Reachability Matrix of enablers

Enablers	1	2	3	4	5	6	7	8	9	10	11
1	1	0	0	1	0	1	1	0	1	1	0
2	1	1	0	0	1	1	1	1	0	1	0
3	0	0	1	1	0	0	1	1	0	0	0
4	0	0	1	1	0	0	0	0	0	0	0
5	1	1	1	1	1	1	1	0	0	1	1
6	1	0	1	0	0	1	0	1	0	0	1
7	0	0	1	0	0	0	1	0	0	0	1
8	0	0	1	0	0	1	1	1	0	1	1
9	1	0	1	1	0	0	0	1	1	0	0
10	1	0	0	1	0	1	0	1	0	1	0
11	0	0	0	0	0	1	1	1	0	0	1

2.4Final reachability matrix

Here, while framing the correlation between various enablers transitivity is also considered. The transitivity rule states thatif a variable A leads to a variable B and if B leads to another variable C, then A leads to C [11]. As per the rule, a final reachability matrix is developed and driving power and dependence of enablers are derived. The total number of ones in the equivalent rows represents driving power and the total number of ones in the equivalent columns of final reachability matrix symbolizes dependence (The row sum is taken as driving power; the column sum is taken as dependence power and is represented as R &C).. Final reachability matrix of the enablers is depicted in table 3.

Table 3 **.**Final reachability Matrix of ICT enabled wireless control system

Enablers	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**Driving Power**

1	1	0	1	1	0	1	1	1	1	1	1	9
2	1	1	1	1	1	1	1	1	1	1	1	11
3	0	0	1	1	0	1	1	1	0	1	1	7
4	0	0	1	1	0	0	1	1	0	0	0	4
5	1	1	1	1	1	1	1	1	1	1	1	11
6	1	1	1	1	1	1	1	1	1	1	1	11
7	0	0	1	1	0	1	1	1	0	0	1	6
8	1	0	1	1	0	1	1	1	0	1	1	8
9	1	0	1	1	0	1	1	1	1	1	1	9
10	1	0	1	1	0	1	1	1	1	1	1	9
11	1	0	1	0	0	1	1	1	0	1	1	7
Dependence	**8**	**3**	**11**	**10**	**3**	**10**	**11**	**11**	**6**	**9**	**10**	

2.5 Level partition

From the final reachability matrix, the reachability and antecedents of each element of enablers are developed. Reachability set consists of a group of enablers itself and other enablers, which it may help to realize, whereas, the antecedent set consists of a group of enablers itself and other enablers, which may help achieving it. The enablers which are common in reachability sets and antecedent leads are assigned at the intersection set. The elements for which reachability and intersection sets are the same occupy the topmost level group (level I group). These top level elements are removed from the set for the formation of the next table. This process is repeated till all levels of each element are found. These levels are exploited for the formation of diagraph and the ISM model. These subsequent iterations are shown in tables 4 to 6.

Table 4. Iteration I

Enablers	Reach ability set	Antecedent set	Intersection set	Level
1	1,3,4,6,7,8,9,10,11	1,2,5,6,8,9,10,11	1,6,8,9,10,11	
2	1,2,3,4,5,6,7,8,9,10,11	2,5,6	2,5,6	
3	3,4,6,7,8,10,11	1,2,3,4,5,6,7,8,9,10,11	3,4,6,7,8,10,11	I
4	3,4,7,8	1,2,3,4,5,6,7,8,9,10	3,4,7,8	I
5	1,2,3,4,5,6,7,8,9,10,11	2,5,6	2,5,6	
6	1,2,3,4,5,6,7,8,9,10,11	1,2,3,5,6,7,8,9,10	1,2,3,5,6,7,8,9,10	
7	3,4,6,7,8,11	1,2,3,4,5,6,7,8,9,10,11	3,4,6,7,8,11	I
8	1,3,4,6,7,8,10,11	1,2,3,4,5,6,7,8,9,10,11	1,3,4,6,7,8,10,11	I
9	1,3,4,6,7,8,9,10,11	1,2,5,6,9,10	1,6,9,10	
10	1,3,4,,6,7,8,9,10,11	1,2,3,5,6,7,8,9,10,11	1,3,4,6,7,8,10,11	
11	1,3,6,7,8,10,11	1,2,3,5,6,7,8,9,10,11	1,3,6,7,8,10,11	I

Table 5.Iteration II

Enablers	Reach ability set	Antecedent set	Intersection set	Level
1	1,6,9,10	1,2,5,6,9,10	1,6,9,10	II
2	1,2,5,6,9,10	2,5,6	2,5,6	
5	1,2,5,6,9,10	2,5,6	2,5,6	
6	1,2,5,6,9,10	1,2,5,6,9,10	1,2,5,6,9,10	II
9	1,6,9,10	1,2,5,6,9,10	1,6,9,10	II
10	1,6,9,10	1,2,5,6,9,10	1,6,9,10	II

Table 6. Iteration III

Enablers	Reach ability set	Antecedent set	Intersection set	Level
2	2,5	2,5	2,5	III
5	2,5	2,5	2,5	III

2.6 Diagraph of ICT enabled wireless control system

Diagraph is the synonym for directed graph, which illustrates the relationship between the elements of enablers as per the numbers assigned to them. Relationship between elements j and i,can be represented by an arrow which points from i to j. Diagraph of the enablers is shown in Figure 1.

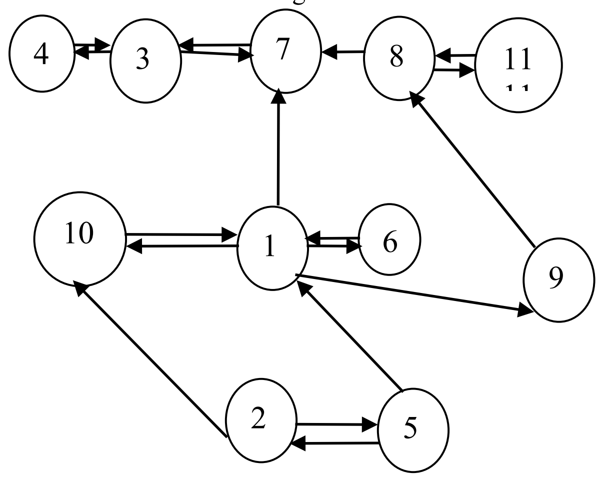

Figure 1 Diagraph of Enablers

2.7 Formation of ISMmodel of enablers of ICT enabled process control system

Diagraph simply represent the directions of relationships and does not give a wide – ranging picture of the context. It is further converted to ISM to get a complete depiction of the inter relationship among the elements of enablers. In the ISM elements of the enablers of the process control system are represented by the statements of elements itself instead of numbers. ISM of enablers of ICT enabled process control system is shown in Figure 2.

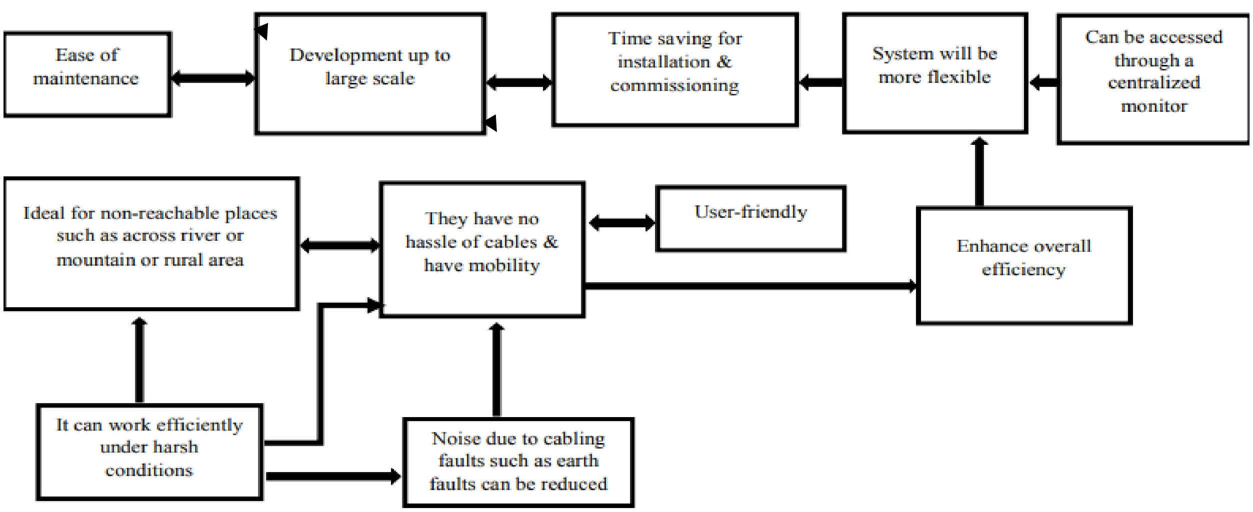

Figure 2.ISMofenablers

2.8 ISMMICMAC Analysis

Theintention of this exploration is to sort out the enablers according to their driving power and dependence (12). The driving power and dependence of each of these enablers are taken from Table 2. Based on that, initially a driver power-dependence diagram is developed as shown in Figure 3. Depending upon the driving power and dependence, enablers of ICT enabled wireless control system have been classified into four clusters. They are (i) autonomous (ii) dependent (iii) linkage and (iv)independent enablers [12].In Figure 3, driving power is marked in the vertical axis and dependence is marked in the horizontal axis. Enabler 1 is having driving power 9 and dependence 8. It is allocated in the appropriate position of (8, 9). Similarly, other enablers are also allocated.Autonomous group has low driving power and low dependence enablers and can be eliminated from the system. Dependent group has low driving power and high dependence enablers. Linkage group has high driving power and high dependence enablers. They are the most important enablers. Any action on this will affect the entire system. Independent group has high driving power and low dependence.

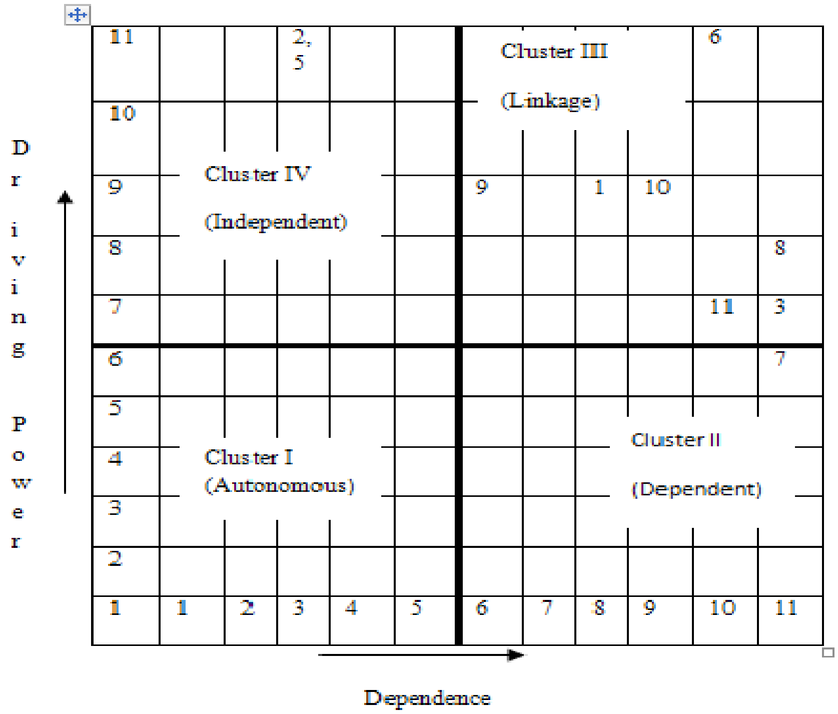

Figure 3.Driving Power Dependence Diagram

The row sum and the column sum of final reachability matrix are known as driving power and dependence power respectively and are represented as R1 &C1. Then final reachability matrix is multiplied to a power of 2. Here the row sum and column sum is taken as R2 & C2. The multiplication process is continued for powers 2,3,4,….etc till a stagnation is reached (the hierarchy of enablers are not changing). So the supremacy of transitivity can be minimized. In this analysis the stagnation has been achieved by raising the power of the matrix to 5. Each time row sum and column sum is calculated and tabulated. Row sums are represented by R1, R2, R3etc and column sum is represented by C1, C2, and C3.etc.Row sum and column sum of the power of matricesof enablers is shown in Table 7.

Table 7.(Row sum and column sum of the power of matrices)

Enablers	**R1**	**C1**	**R2**	**C2**	**R3**	**C3**	**R4**	**C4**	**R5**	**C5**
1	8	9	44	30	255	175	1461	1011	8363	5809
2	3	11	18	40	94	227	525	1296	2990	7418
3	11	7	48	66	279	394	1603	2281	9188	13101
4	10	4	57	33	335	187	1931	1069	11075	6122
5	3	11	14	66	76	394	431	2281	2465	13101
6	10	11	18	40	94	227	525	1296	2990	7418
7	11	6	59	12	350	58	2026	313	11640	1761

8	11	8	66	23	394	134	2281	773	13101	4436
9	6	9	56	23	328	121	1887	675	10820	3841
10	9	9	14	61	76	364	431	2106	2465	12090
11	10	7	57	82	445	642	3449	4976	13411	13156

A comparison is made between R1 R2, R2 R3 and so on until the rank of the driving power and dependence power remains the same, i.e. maximum to minimum value of the driving power remains the same for the sameenabler. Repeat the process for the dependence power.A matrix is said to be in stagnation when the driving power and the dependence power ranks remains the same for the same enablers even though matrix is multiplied to higher powers.Driving power and Dependence power ranks of enablers for stagnation matrix is shown in Table 8. When comparing R4 and R5, C4 andC5 the value remains the same.So the matrix is said to be in stagnation.For example enabler 1 is keeping 6th position in driving power for 4th power of Multiplication of the final reachability matrix and 5th power of multiplication of the final reachability matrix as shown in table8.For the same enabler the rank of dependence power is 3rd position for the 4th power of final reachability matrix. This position remains the same for further multiplication.(Table8). Stagnation of the final reachability matrix is obtained for a power of 4.. MATLAB function is used for matrix multiplication.

Table 8.Driving power and Dependence power ranks of enablers for stagnation matrix

Enablers	**R4**	**R5**	**C4**	**C5**
1	6	6	3	3
2	7	7	1	1
3	3	3	6	6
4	1	1	5	5
5	7	7	1	1
6	7	7	5	5
7	2	2	6	6
8	5	5	6	6
9	6	6	2	2
10	6	6	4	4
11	4	4	5	5

Based on this hierarchy, Matriced'ImpactCroises multiplicationAppliqueeaunclassment or Cross impact matrix-multiplication applied to classification (MICMAC) matrix has been made.(Figure 4). The MICMAC analysis helps to identify the key enablers, that is to say, those essential to the system's implementation. Comparison of the hierarchy of enablers in the various classifications is a rich source of information. It enables one not only to confirm the importance of certain variables but also to reveal that variables which, because of their indirect actions, play an important role (yet were not identifiable through direct classification) [16, 17].

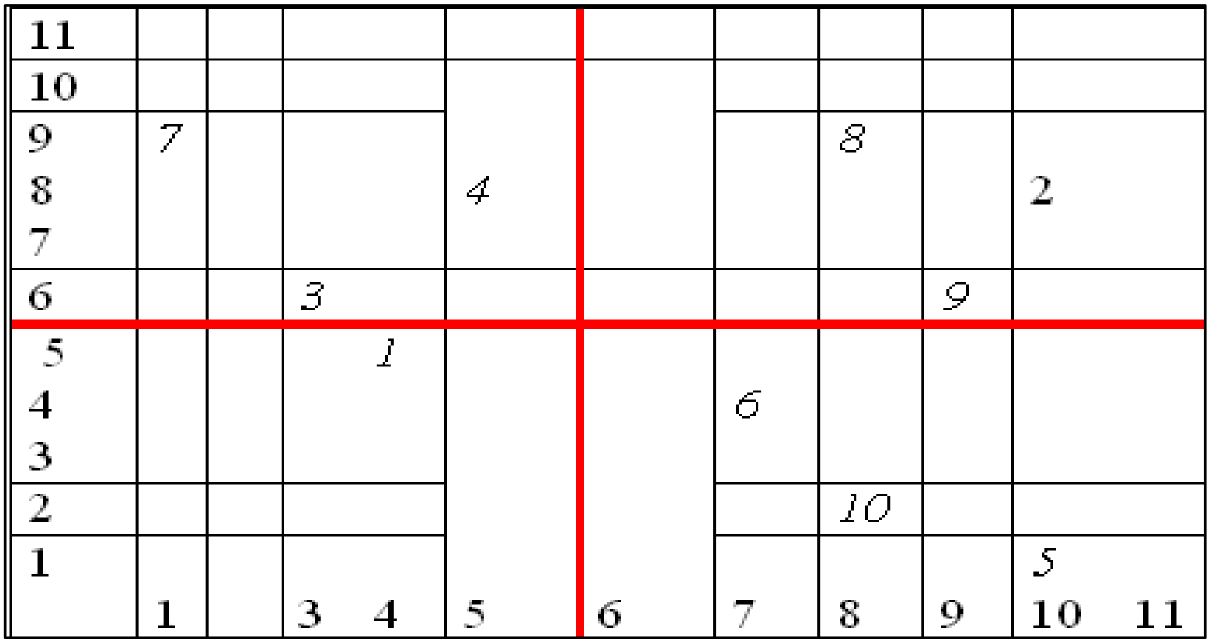

Figure 4. ISM MICMAC analysis

2.9Fuzzy ISM

It is an advanced ISM, which is based on the assumption that there exists variation in the interrelationships between the enablers in ISM [15]. In ISM binary numbers are used to assign values to the interrelationship between the enablers. No intermediate values can be assigned to the various correlations between the enablers. Analysis that is more precise can be made by assigning intermediate values [13]. This makes fuzzy logic a more natural approach to this kind of problems [18,19]. In this regard, by discussing with the experts the interrelationships among the enablers considering their fuzziness were finalized. They were requested to prioritize in the scale 0-1 (0= No relationship and 1=Good relationship). The average of the ripostes of 10 experts has been concluded in this regard. Using this method, the decision-makers fuzzy assignments with different rating viewpoints are considered in the aggregation procedure to ensure more accurate decision-making. The interrelationships established in this regard are shown in Table 9. This matrix has been multiplied several times to get the stagnation matrix. It is pictorially represented as fuzzy ISM in figure 5.Hierarchy of enablers based on driving power and dependence of variables while incorporating fuzziness is given in the table 10.Based on this a Fuzzy MICMAC matrix is developed as shown in the figure 6.

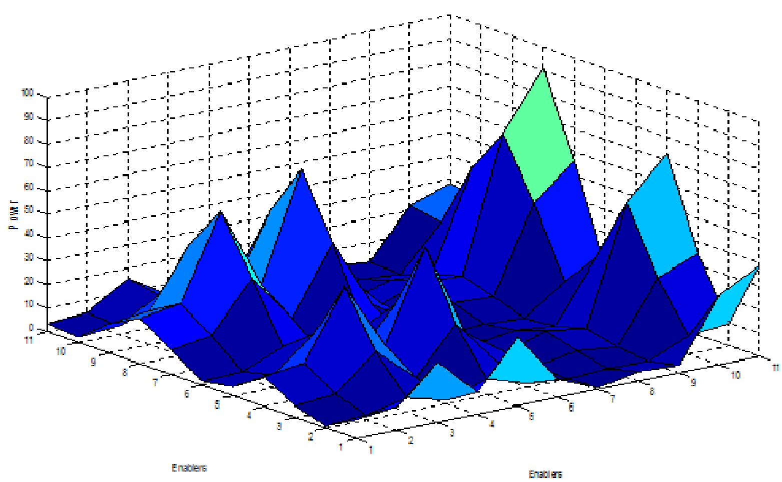

Figure 5. Fuzzy ISM

Table 9. Interrelationships between variables considering their fuzziness

Enablers	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
1	1	.5	.6	.4	.1	.1	0	0	.1	0	.1
2	0	1	.2	0	.1	0	0	0	0	.1	.1
3	.1	.1	1	.1	.3	.1	0	.1	0	.7	.3
4	.5	.1	.3	1	1	.1	0	.1	.2	.3	1
5	0	0	.7	0	1	0	0	0	0	.1	1
6	0	0	.3	0	.2	1	0	0	0	.1	.2
7	0	.4	.2	.5	.3	.2	1	.1	.2	.3	.3
8	.4	.3	.4	.6	.4	.8	.4	1	.4	.1	.4
9	.6	.2	.3	.3	.6	.4	.1	0	1	.1	.6
10	0	0	.2	0	.5	0	0	0	0	1	.5
11	0	.1	0	.1	.3	.1	0	.1	0	.7	1

Table 10: Hierarchy of enablers based on driving power and dependence of variables while incorporating fuzziness

Enablers	Driving power	Dependence
1	5	4
2	8	10
3	6	3
4	10	3
5	1	10
6	5	6
7	9	1
8	1	5
9	6	9
10	2	3
11	4	8

11											
10			*4*								
9	*7*										
8										*2*	
7											
6			*3*						*9*		
5				*1*		*6*					
4								*11*			
3											
2			*10*								
1					*8*						*5*
	1	2	3	4	5	6	7	8	9	10	11

Figure 6. Fuzzy MICMAC Matrix

In the selected enablers1, 8 and 10 are coming under autonomous. Autonomous elements are very weak so it can even be eliminated from the system. The second cluster elements are 5, 6 and 11.They are having high dependent power and small driving power and are coming under dependent. The elements 2 and 9are coming under 3rd cluster (linkage). Elements in the linkage are key enablers. They are considered as very powerful enablers who can affect the system and should be handled carefully. Elements 3,4 and 7 are under 4th cluster- independent group. They have high driving power and low dependence power. They will also affect the system. In fuzzy MICMAC analysis a 'transition region' is also considered which is shown in blue color.

3. Results and Discussions

The proposed Fuzzy ISM model is an endeavor for identifying the key enablers that influence the implementation of ICT enabled wireless control system in process industries. An analysis of the driving power dependence diagram, ISM MICMAC and FUZZY MICMAC shows that FUZZY MICMAC is the precise method to identify the key enablers. After discussing with three industrial experts in the GM level and two experts from academia, an action plan has been formulated for enhancing the key enablers for the successive implementation of ICT enabled wireless control in industry.

Based on the fuzzy MICMAC, the following findings are reported:

1) The essential factors for the successful implementation of ICT enabled control system in process industries could be understood in advance.

2) Fuzzy MICMAC helps to identify the key enablers from the eleven enablers.

3) With the help of experts in industry and academia, by nourishing the identified enablers, ICT enabled wireless control system can be implemented in the industry.

4) Implementation of the ICT enabled wireless control system decreases the usage of several instruments in the process, thereby cutting down the costs and increases overall efficiency of the system.

As a future scope the research can be further extended by incorporating more enablers. Hypothesis testing and management modeling further catalyzes the relationships. Similar research is possible for inhibitors of ICT enabled process control system, which is under progress.

4. Conclusion

The fields of management are swarming with innumerable models and elicitations of experts. ISM is well proven to utilize the experts' knowledge and experience [14]. This research illustrates theinter - relationships between the enablers of ICT enabled wireless control system using ISM. Further, by the introduction of Fuzzy ISM more precise identification of the key enablers has been made. In this work, eleven enablers of ICT enabled wireless control system were identified and considered for analysis. The identification of the key enablers and awareness of their driving power and dependence from the Fuzzy MICMAC help the experts in industry to focus on them and prioritize them for successfully implementing ICT enabled wireless control systems. This study thus helps the industrialists to enhance the key enablers, which will be highly beneficial to the process industries.

Reference

Hollenstein,H "Determinants of the adoption of ICT: An empirical analysis based on firm-level data for the Swiss business sector", *Structural Change and Economic Dynamics*, Vol 15, Issue 3, pp 315–342, 2004.

Bidarian,S,Bidarian,SAmirhoseinDavoudi, M; "A Model for application of ICT in the process of teaching and learning", *Procedia - Social and behavioral Sciences*, Vol 29, pp 1032–1041,2011.

A,Thompson,H "Wireless and Internet communications technologies for monitoring and control", *Control Engineering Practice*, Vol 12, Issue 6, pp 781–791, 2004.

http:// freewimaxinfo.com/point-to-point wireless networks.html

B.P. Sharma ,M.D. Singh , Neha, "Knowledge Sharing Barriers: An Approach of Interpretive Structural Modeling ",*The IUP Journal of Knowledge Management*, Vol. X, No. 3, pp. 35-52, 2012,

Mandal.A. and Deshmukh .S. G, "Vendor selection using interpretive structural modeling(ISM)", *International journal of Operations and production management,*Vol 14, no:6,pp.52-59, 1994.

Warfield, J.N,;*A Science of Generic design: Managing complexity through systems design*, Iowa state university press, Ames, I.A, 1974

Thakkar .J, Deshmugh,S.G. Gupta A.D and Shankar.R., An integrated approach of Interpretive structural modeling and analytic network process., *International journal of productivity and Performance management*, vol.56, no: 1, pp.25-59, 2007.

Faizal, M.N; Banwet.D.K and Shankar.R., "Supply chain risk mitigation: modeling the enablers ",*Business process Management Journal,*Vol 12,no:4,pp.535-552, 2006

Tripathy,S,Sahu, S, Ray,P K., "Interpretive Structural Modelling for Critical Success Factors of R&D Performance in Indian Manufacturing Firms", *Journal of Modelling in Management*, Vol. 8 Iss: 2, 2013.

Pramodand.Banwet D.K., Interpretive structural modeling for understanding the inhibitors of a telecom service supply chain.(*IEOM)(Dhaka, Bangladesh),* Jan -9-10, 2010.

Attri,R, Dev ,N and Sharma, V, Interpretive Structural Modelling (ISM) approach: An Overview, *Research Journal of Management Sciences*,Vol.2(2) pp,3-8, 2013 .

M.K. Khurana, P.K. Mishra, Jain,R,A.R.Singh.,Modeling of Information Sharing Enablers for building Trust in Indian Manufacturing Industry: An Integrated ISM and Fuzzy MICMAC Approach ;*InternationalJournal of Engineering Science and Technology*;Vol. 2(6), 1651-1669, 2010.

Kumar, S,Luthra,S and Haleem, A., Customer involvement in greening the supply chain: an interpretive structural modelling methodology.*InternationalJournal ofIndustrial Engineering*,9:6,pp:1-13,2013.

Patidar, L, Soni,V K and Soni ,P K., Manufacturing wastes analysis in lean environment: an integrated ISM-fuzzy MICMAC approach; *International Journal of System Assurance Engineering and Management*, November 2017, Volume 8, Supplement 2, pp 1783–1809, 2016

Dewangan DK, Agrawal R, Sharma V., Enablers for competitiveness of Indian manufacturing sector: An ISM-fuzzy MICMAC analysis. *ProcediaSocBehavSci* 189:416–432,2015

Singh, R K and Gupta, A., Framework for sustainable maintenance system: ISM–fuzzy MICMAC and TOPSIS approach,*Annals of Operations Research* ,pp 1–34 ,2019

Wang,W,Liu, X,Qin, Y, Huang, J ,Liu, Y., Assessing contributory factors in potential systemic accidents using AcciMap and integrated fuzzy ISM - MICMAC approach; *International Journal of Industrial Ergonomics*,Volume 68, Pages 311-326, 2018

Katiyar, R,Barua, M. K., Purushottam L. Meena., Analyzing the Interactions Among the Barriers of Supply Chain Performance Measurement: An ISM with Fuzzy MICMAC Approach ,*GLOBAL BUSINESS REVIEW*, September 25, pp. 48–68, 2017

Biographies

Dr. JayalakshmiB is a Professor in Instrumentation and Control Engineering Departmentof NSS College of Engineering, India. She holds a Bachelor's degree in Instrumentationand Control Engineering from NSS College of Engineering, India, a Master'sdegree in Instrumentation and Control Systems from National Institute of Technology, Kozhikode, India and PhD in Process Control from Karpagam University, INDIA .She has twenty-eight years of teaching experience.She has published eight papers in international journals, one in a reputed national journal and twenty papers in the proceedings of the leading National and International Conferences. Her areas of research interest include wireless remote control of processes using information and communication technology, process control Instrumentation and transducers.

Haritha H is working as a Programmer Analyst in Cognizant Technology Solutions, Info park-Cochin, Kerala, India. Her academic history complies of a Bachelor's degree in Electrical and Electronics Engineering from NSS College of Engineering, Palakkad, Kerala, India followed by a Master's degree in VLSI Design from Amrita School of Engineering, Coimbatore, India. She has an experience of two years in IT sector and in the meanwhile she has presented two papers in the national conferences and three in IEEE international conferences. Her areas of research interests include VLSI Design and Wireless Remote Control of Processes.

Abijith Maniyeri is an on-going post-graduate student pursuing Master's degree in Electrical and Electronics Engineering from University of Southern Queensland (USQ), Australia. He holds a Bachelor's degree in Electrical and Electronics Engineering from NSS College of Engineering, Palakkad, Kerala, India. Till the present, he has presented two papers in the IEEE international conferences. His areas of research interests include Sensors and Instrumentation and Wireless Remote Control of Processes.