Proceedings of the 2014 International Conference on Industrial Engineering and Operations Management
Bali, Indonesia, January 7 – 9, 2014

Interpretive Structural Modeling of the Inhibitors of Wireless Control System in Industry

Jayalakshmi B.
Mechanical Department, Karpagam University, Coimbatore, Tamil Nadu, India
Instrumentation and Control Engineering Dept, NSS College of Engineering, Palakkad, Kerala, India

Pramod. V. R.
Department of Mechanical Engineering, NSS College of Engineering
Palakkad-8, Kerala, India

Abstract

The use of Information and communication technology (ICT) enabled wired process control systems has become an incumbent trend in process industry. In order to facilitate it, they commonly use Distributed control system, Supervisory control and data acquisition systems with wireless open loop control systems. Still, wireless closed loop control systems are not introduced in the process industry. So; here the authors try to analyze the inhibitors of implementing ICT enabled control system in the process industry, effectively establishing their correlations by interpretive structural modeling (ISM). Here is an attempt to unfold ISM with the use of structural self-interaction matrix, Initial reach ability matrix, and final reach ability matrix. During the second phase, a diagraph is prepared and converted to ISM. We conclude the paper with an action plan to concentrate on high driving power elements and with managerial implications.

Keywords
ICT, ISM, inhibitors, structural self-interaction matrix, initial reach ability matrix, final reach ability matrix, level partition, diagraph, driving power, dependence

1. Introduction

There are numerous benefits for the adoption of ICT technology [1].Implementation of different types of educational programs using ICT has become a new trend in education [2]. A Surfeit of research is going on in internet based control systems by accessing data wirelessly from a remotely located process. Wireless and Internet communications technologies are used to monitor and control of such systems [3]. Apart from the mobility of the device within the environment, a wireless communication system has numerous other advantages. It is easy to add a communication device to the system or to remove it without any disruption to the remainder of the system. Once the initial outlay of setting up cell sites are over, there is only minimal cost for running and maintaining a radio based communication solution. There are numerous other factors too to prove the appeal for a radio communication system in the office environment. Wireless interface is extremely risky for official private information, as it is a public frequency network. The rapidity and feasibility of the wireless signals decline with the increase in the number of users who utilize the same frequencies. With the use of high speed point-to-point wireless networking and wireless backhaul, these shortcomings of the wireless network can be overcome to a great extent. Point-to-point wireless networking uses series topology instead of mesh. This increases the radial distance coverage and overcomes geographical barriers. The network is invisible and so not easy to hinder. There is also an alternate solution that helps restoring the connectivity when interrupted. Wireless backhaul is an economic connection with numerous applications. It can handle a huge amount of data uploading, and down loading in a blink of an eye [4].

Enough researches are not yet done in emerging systematic design methods using this technology or in designing ICT enabled process control systems. Many open loop wireless control systems like wireless transmitter and ICT enabled Control valves are available in the process industry. Yet industrialists have not dared to implement these innovative methods for a closed loop system. With the introduction of security methods like wired equivalent privacy 2 (WEP2),point-to-point wireless networking and wireless backhaulin the network, ICT enabled process control system can be effectively used in industry. In the current work, authors make an attempt to analyze the inter relationships between the inhibitors of implementing such a system in industry using Interpretive Structural Modeling (ISM).

2. Interpretive structural modeling (ISM) Methodology

ISM can be used to effectively access the interrelationships among the various elements and their degree of associations. The most prominent knowledge sharing barriers that should be seriously considered can be determined using ISM. Based on correlation, an overall pattern is carrying out from the complex set of variables [6; 7; 8 and 9].The methodology can be seen effectively used in determining the critical success factors of R&D Performance in Indian Manufacturing Firms [10]. For framing the aims and objectives of this work, a brainstorming session with about 15 experts from industry possessing in-depth knowledge and high potential in the field derives the inhibitors of ICT enabled process control systems. ISM interrelates these inhibitors. Structural self-interaction matrix, initial reach ability matrix, final reach ability matrix and diagraph have been made for this purpose; and diagraph is converted to ISM. After the observation of the driving power-dependence graph, an action plan is prepared for the study.

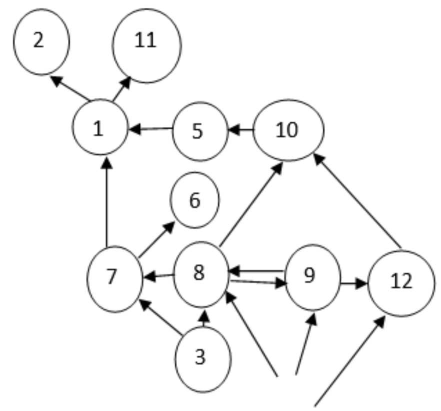


Figure 1: Diagraph of inhibitors of ICT enabled process control system

2.1. **Inhibitors of ICT enabled process control system.**

Direct and telephonic interviews are conducted with about 15 experts from leading process industries with thorough knowledge in the field. Also from conducting surveys, the inhibitors of ICT enabled process control system have the following attributes:

1) No standard from any international organization (ISA etc) recommending wireless for closed loop.
2) Since existing systems are available with controllers, Separate micro controller increases cost and installation difficulty.

3) Reliability of network hardware is difficult to ensure when used in industrial conditions.
4) Less secure.
5) Monitoring the conditions of components in a highly distributed system will be difficult.
6) Most networks related hardware and protocols are frequently enhanced for security and other reasons. So a number of system components may face obsolescence very quickly.
7) Comparatively low speed of communication.
8) Wireless technology is an unstable network.
9) Wireless signals are prone to disrupt by the infrared and radio signals.
10) More complex to configure than wired network.
11) Highly expensive.
12) Limited spectrum available for communication

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

Structural self-interaction matrix **(**SSIM) provides the direction of appropriate relationships among the components of inhibitors. Column one shows the inhibitors and columns two to thirteen show the same elements arranged in reverse order. SSIM thus developed is shown in Table 1.

Table 1: Structural self-interaction matrix of inhibitors

inhibitors	12	11	10	9	8	7	6	5	4	3	2	1
1	A	V	O	O	O	X	O	A	A	O	X	1
2	O	O	X	O	A	A	X	V	A	A	1	
3	V	V	O	O	V	V	O	O	A	1		
4	V	O	O	X	V	V	O	X	1			
5	A	O	X	A	A	O	O	1				
6	O	X	O	O	O	A	1					
7	X	O	O	X	A	1						

8	O	V	X	X	1							
9	V	O	X	1								
10	X	O	1									
11	O	1										
12	1											

2.3. Initial Reachability matrix (IRM) of inhibitors.

Here the SSIM of the table above has been converted into a matrix of binary elements named as IRM. In this regard following rules are used 1)If the (i,j) 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) For the letter A in the SSIM ,(i,j)entry in the reach ability matrix is 0 and (j,i) entry is 1.(3) For X in the SSIM, (i,j) entry in the reach ability matrix is 1 and (j,i) entry is 1.(4) If O is in the SSIM , then substitute 0 in both the (i,j) and (j,i) entries of the reach ability matrix. IRM thus developed is shown in Table 2.

Table 2: Initial reachability matrix of inhibitors of ICT enabled process control system

inhibitors	1	2	3	4	5	6	7	8	9	10	11	12
1	1	1	0	0	0	0	1	0	0	0	1	0
2	1	1	0	0	1	1	0	0	0	1	0	0
3	0	1	1	0	0	0	1	1	0	0	1	1
4	1	1	1	1	1	0	1	1	1	0	0	1
5	1	0	0	1	1	0	0	0	0	1	0	0
6	0	1	0	0	0	1	0	0	0	0	1	0
7	1	1	0	0	0	1	1	0	1	0	0	1
8	0	1	0	0	1	0	1	1	1	1	1	0
9	0	0	0	1	1	0	1	1	1	1	0	1
10	0	1	0	0	1	0	0	1	1	1	0	1
11	0	0	0	0	0	1	0	0	0	0	1	0
12	1	0	0	0	1	0	1	0	0	1	0	1

2.4 Final Reachability matrix

While forming the correlation between various enablers transitivity is also considered here. According to the transitivity rule, if a variable A leads to a variable B and if B leads to another variable C, then A leads to C[11]. So here, a final reach ability matrix is developed for deriving the driving power and dependence of inhibitors. Driving power is the total number of ones in the equivalent rows of final reach ability matrix and the total number of ones in the equivalent columns symbolizes dependence. Final reachability matrix of the inhibitors is shown in Table 3.

Table 3: Final reachability Matrix of inhibitors

inhibitors	1	2	3	4	5	6	7	8	9	10	11	12	Driving power
1	1	1		1	1	1	1		1	1	1	1	10
2	1	1		1	1	1	1	1	1	1	1	1	11
3	1	1	1		1	1	1	1	1	1	1	1	11
4	1	1	1	1	1	1	1	1	1	1	1	1	12
5	1	1	1	1	1		1	1	1	1	1	1	11
6	1	1			1	1				1	1		6
7	1	1		1	1	1	1	1	1	1	1	1	11
8	1	1		1	1	1	1	1	1	1	1	1	11
9	1	1	1	1	1	1	1	1	1	1	1	1	12
10	1	1		1	1	1	1	1	1	1	1	1	11
11		1				1					1		3
12	1	1		1	1	1	1	1	1	1	1	1	11
Dependance	11	12	4	9	11	11	10	9	10	11	12	10	

2.5 Level partition

The final reachability matrix develops the reachability and antecedent sets of each element of inhibitors. Reachability set of inhibitor one can be obtained by collecting the elements having the value “one” in the first row of final reachability matrix. Antecedent set of inhibitor one can be obtained by collecting the elements having the value "one" in the first column of final reachability matrix. The inhibitors that are common in the reachability sets and antecedent sets are assigned at the intersection set. For some elements the reachability and intersection sets are the same; they occupy the topmost level group (level I group). These elements are avoided while forming the set for the next table. This process is repeated till finding all levels of each element. All these levels are made use of 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	1,2,4,5,6,7,9,10,11,12	1,2,3,4,5,6,7,8,9,10,12	1,2,4,5,6,7,9,10,12	
2	1,2,4,5,6,7,8,9,10,11,12	1,2,3,4,5,6,7,8,9,10,11,12	1,2,4,5,6,7,8,9,10,11,12	I
3	1,2,3,5,6,7,8,9,10,11,12	3,4,5,9	3,5,9	
4	1,2,3,4,5,6,7,8,9,10,11,12	1,2,4,5,7,8,9,10,12	1,2,4,5,7,8,9,10,12	
5	1,2,3,4,5,7,8,9,10,11,12	1,2,3,4,5,6,7,8,9,10,12	1,2,3,4,5,7,8,9,10,12	
6	1,2,5,6,10,11	1,2,3,4,6,7,8,9,10,11,12	1,2,6,10,11	
7	1,2,4,5,6,7,8,9,10,11,12	1,2,3,4,5,7,8,9,10,12	1,2,4,5,7,8,9,10,12	
8	1,2,4,5,6,7,8,9,10,11,12	2,3,4,5,7,8,9,10,12	2,4,5,7,8,9,10,12	
9	1,2,3,4,5,6,7,8,9,10,11,12	1,2,3,4,5,7,8,9,10,12	1,2,3,4,5,7,8,9,10,12	
10	1,2,4,5,6,7,8,9,10,11,12	1,2,3,4,5,6,7,8,9,10,12	1,2,4,5,6,7,8,9,10,12	
11	1,6,11	1,2,3,4,5,6,7,8,9,10,11,12	1,6,11	I
12	1,2,4,5,6,7,8,9,10,11,12	1,2,3,4,5,7,8,9,10,12	1,2,4,5,7,8,9,10,12	

Table 5: ITERATION II

Enablers	**Reach ability set**	**Antecedent set**	**Intersection set**	**Level**
1	1,4,5,6,7,9,10,12	1,3,4,5,6,7,8,9,10,12	1,4,5,6,7,9,10,12	II
3	1,3,5,6,7,8,9,10,12	3,4,5,9	3,5,9	
4	1,3,4,5,6,7,8,9,10,12	1,4,5,7,8,9,10,12	1,4,5,7,8,9,10,12	
5	1,3,4,5,7,8,9,10,12	1,3,4,5,6,7,8,9,10,12	1,3,4,5,7,8,9,10,12	II

6	1,5,6,10	1,3,4,6,7,8,9,10,12	1,6,10	
7	1,4,5,6,7,8,9,10,12	1,3,4,5,7,8,9,10,12	1,4,5,7,8,9,10,12	
8	1,4,5,6,7,8,9,10,12	3,4,5,7,8,9,10,12	4,5,7,8,9,10,12	
9	1,3,4,5,6,7,8,9,10,12	1,3,4,5,7,8,9,10,12	1,3,4,5,7,8,9,10,12	
10	1,4,5,6,7,8,9,10,12	1,3,4,5,6,7,8,9,10,12	1,4,5,6,7,8,9,10,12	II
12	1,4,5,6,7,8,9,10,12	1,3,4,5,7,8,9,10,12	1,4,5,7,8,9,10,12	

Table 6: ITERATION III

Enablers	Reach ability set	Antecedent set	Intersection set	Level
3	3,6,7,8,9,12	3,4,9	3,9	
4	3,4,6,7,8,9,12	4,7,8,9,12	4,7,8,9,12	
6	6	3,4,6,7,8,9,12	6	III
7	4,6,7,8,9,12	3,4,7,8,9,12	4,7,8,9,12	
8	4,6,7,8,9,12	3,4,7,8,9,12	4,7,8,9,12	
9	3,4,6,7,8,9,12	3,4,7,8,9,12	3,4,7,8,9,12	
12	4,6,7,8,9,12	3,4,7,8,9,12	4,7,8,9,12	

Table 7: ITERATION IV

Enablers	Reach ability set	Antecedent set	Intersection set	Level
3	3,7,8,9,12	3,4,9	3,9	
4	3,4,7,8,9,12	4,7,8,9,12	4,7,8,9,12	
7	4,7,8,9,12	3,4,7,8,9,12	4,7,8,9,12	IV
8	4,7,8,9,12	3,4,7,8,9,12	4,7,8,9,12	IV
9	3,4,7,8,9,12	3,4,7,8,9,12	3,4,7,8,9,12	IV
12	4,7,8,9,12	3,4,7,8,9,12	4,7,8,9,12	IV

Table 8: ITERATION V

Enablers	Reach ability set	Antecedent set	Intersection set	Level
3	3	3,4	3	V
4	3,4	4	4	

Table 9: ITERATION VI

Enablers	Reach ability set	Antecedent set	Intersection set	Level
4	4	4	4	VI

2.6 Diagraph of inhibitors ICT enabled process control system

The diagraph simply shows the relationship between the elements of inhibitors according to the numbers assigned to them. The arrow which points from I to j represents the relationship between elements j and i. Diagraph of inhibitors is shown in figure 2.

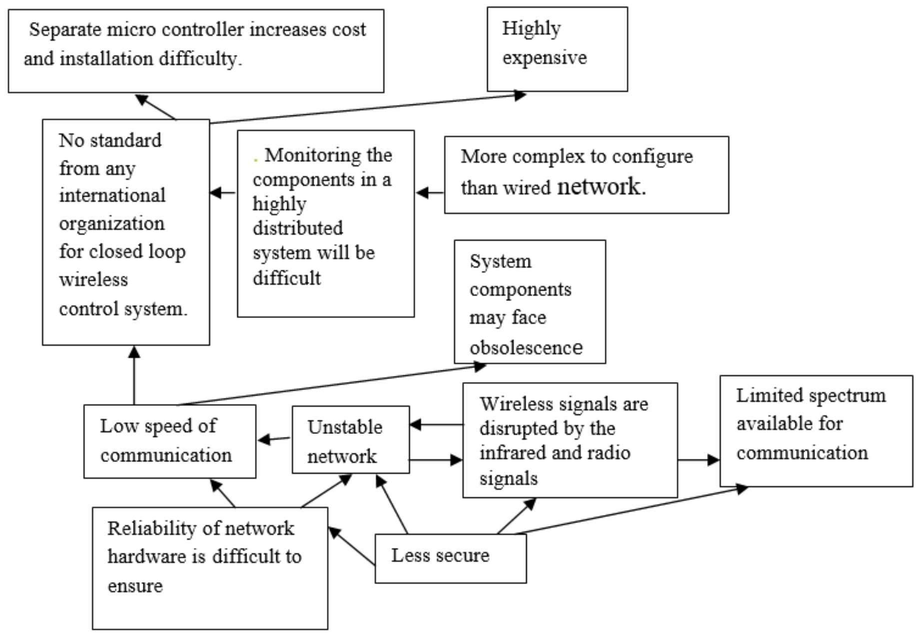
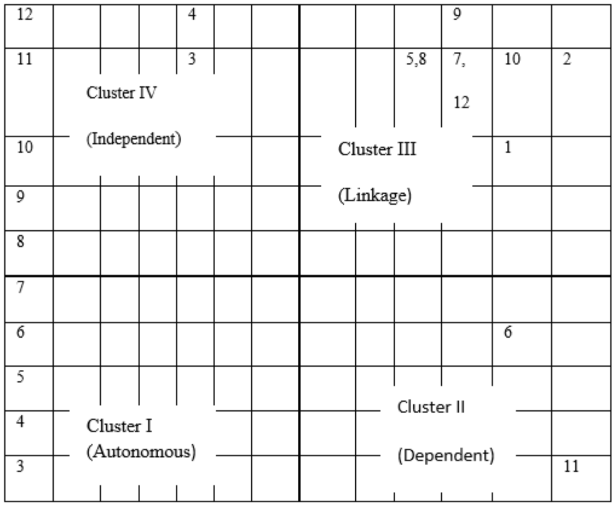


Figure 2: ISM of inhibitors of ICT enabled process control system

2.7 ISM of inhibitors of ICT enabled process control system

For getting the complete depiction of the inter relationship among the elements, diagraph is converted to ISM. In the ISM nodes of the inhibitors are represented by the statements. ISM of inhibitors of ICT enabled process control system is shown in Figure 3.

2.8 Driving power-dependence diagram of inhibitors ICT enabled process control system



2.8 Driving power-dependence diagram for inhibitors

A graph which classifies the inhibitors into four clusters is drawn (as shown in the graph 1) based on the driving power and dependence. These clusters are (i) Autonomous. (ii) Dependent (iii) linkage and (iv) independent [12]. Among this the Autonomous group shows low driving power and low dependence inhibitors; so they can be eliminated from the system. Dependent group has low driving power and high dependence inhibitors. Linkage group is with high driving power and high dependence inhibitors which are the most important ones. Any action on this will affect the entire system. Independent group has high driving power and low dependence.

2.9 **Action plan based on study**

An action plan is developed to enhance the elements of linkage group as a result of the discussion with three industrial experts in the GM level and two experts from academia.

3. Results and Discussions

This is an endeavor to identify and summarize the interrelationships among the inhibitors that influence the implementation of ICT enabled control system in process industries. The following findings are reported based on the interrelationship:

1) There are many obstacles for the successful implementation of ICT enabled control system in process industries; they could be understood in advance.

2) Determination of major inhibitors using ISM will help to make the installation easy.

4. Conclusion

This is an attempt to illustrate the inter relationships between the inhibitors of ICT process control system using ISM.The common practice to study the performance of a system is to develop a standard model. Here in this work, twelve inhibitors of ICT enabled process control system were identified and considered for analysis. This identification and understanding of their driving power and dependence help the experts in industry to focus on inhibitors and steer clear of them for the successful implementation of ICT enabled process control systems. Further analysis also is possible for fuzzy ISM of inhibitors of ICT enabled process control system, which is under progress.

References

[1] Heinz Hollenstein, Determinants of the adoption of ICT: An empirical analysis based on firm-level data for the Swiss business sector, Structural Change and Economic Dynamics, Volume 15, Issue 3, 2004, Pages 315–342.

[2] Shabnam Bidarian, soheila Bidarian, Amirhosein Mohammad Davoudi; A Model for application of ICT in the process of teaching and learning, *Procedia - Social and behavioral Sciences, Volume 29, 2011, Pages 1032–1041*.

[3] Haydn .A. Thompson, Wireless and Internet communications technologies for monitoring and control, Control Engineering Practice, Volume 12, Issue 6, June 2004, Pages 781–791
[4] http:// freewimaxinfo.com/point-to-point wireless networks.html
[5] B.P. Sharma ,M.D. Singh , Neha 2012,"Knowledge Sharing Barriers: An Approach of Interpretive Structural Modeling",*The IUP Journal of Knowledge Management, Vol. X, No. 3, July 2012, pp. 35-52*
[6] Mandal.A. and Deshmukh .S. G.(1994) 'Vendor selection using interpretive structural modeling(ISM)', international journal of Operations and production management,vol14,no:6,pp.52-59.
[7] Warfield, J.N, 1974; a Science of Generic design: Managing complexity through systems design, Iowa state university press, Ames, I.A
[8] Thakkar .J, Deshmugh,S.G. Gupta A.D and Shankar.R.,2007, 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.
[9] Faizal, M.N; Banwet.D.K and Shankar.R, 2006,"Supply chain risk mitigation: modeling the enablers ",Business process Management Journal, Vol 12,no:4,pp.535-552.
[10] Sushanta Tripathy, Sadananda Sahu, Pradip Kumar Ray, (2013) "Interpretive Structural Modeling for Critical Success Factors of R&D Performance in Indian Manufacturing Firms", Journal of Modeling in Management, Vol. 8 Iss: 2
[11] Pramod and.Banwet D.K 2010, Interpretive structural modeling for understanding the inhibitors of a telecom service supply chain (IEOM) (Dhaka, Bangladesh), Jan -9-10, 2010.
[12] Rajesh Attri, Nikhil Dev and Vivek Sharma, Interpretive Structural Modeling (ISM) approach: An Overview, Research Journal of Management Sciences, Vol.2 (2), 3-8, February (2013).