Performance Measure Of Industrial Robotics In Lean Enterprise: A Case Study In Semiconductor Industry

P.A.Perumal, S.Hammam, C.C.Tay

ABSTRACT: Industrial robotics replaced human workers in almost all fields due to their abilities to multitask, flexibility and configurability in any position they involved in. However, implementing industrial robotics is challenging due to their high cost, expert handling, and complexity. The object of this study is to determine the performance measurement using the QCDAC method or (quality, cost, delivery, accountability and continual improvement) then categorized according to lean principles and then identifying seven main areas that the industrial robotics contributes in the semi-conductor company. The performance identification and ranking is done by using Interpretive Structural Modelling (ISM) methodology to identify the most affected performance of the model and to clarify the industrial robotics performance in these areas in which the industrial robotics fit and compatible with the lean enterprise. Human- robot interaction considered to guarantee the workers' safety working alongside industrial robotics. The result of the ISM method shows the performance measure that affects the industrial robotics to support lean enterprise in terms of quality improvement, cost reduction and efficiency.

KEYWORDS: Lean enterprise, industrial robotics, human interaction, interpretive structural modeling

1 INTRODUCTION

The industrial robotics technologies made a competitive climate between companies with the support of lean enterprise, the manufacturer will become a world class manufacturer. The performance of the industrial robotics in lean enterprise has two sides always one side thinking that the industrial robotics add complexity and it's too ridged in the production line and the other side thinks that the industrial robotics improve the production line.

Revised Manuscript Received on June 01, 2019.
P.A.Perumal, S.S.Yoon, Faculty of Manufacturing Engineering, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya,76100 Durian Tunggal, Melaka, Malaysia.
C.C.Tay, Faculty of Electrical Engineering, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya,76100 Durian Tunggal, Melaka, Malaysia.

As [1] highlighted lately robotics plays a very important role in human life and that's because the artificial intelligence technology which made the communication with robotics easier and in an intelligent way. [2] Mentioned about the competitive environment between companies always encourage them use the latest technology in order to improve faster than other companies. The significance of the study is about the industrial robotics compatibility to lean enterprise in terms of improving the products quality and reducing defects.

Ayres [3] highlighted the benefits gained from robotics such as enhance the life quality level. As this technology advance in a fast rate it eliminates the human touch in some dirty, dangerous and repetitive tasks. Lean enterprise is "a group of individuals, functions, and legally separate but operationally synchronized companies"[4].Dimancescu, Hines, and Rich [5] clarified that the meaning of the whole system management is to examine all the added value activities and not just total of separate parts. Glaser [6] highlighted that the industrial robotics contribution in lean principles or few areas where industrial robotics overlap the lean manufacturing model which can be grouped in the three principles of lean, firstly making a smooth or continuous flow toward the customer the industrial robotics can help in this stage by cellular manufacturing. Secondly the pull production principle and in the step the robot will only perform a task based on an order. Lastly seeking perfection principle by production planning which mean that robots easily serves as the conductor in a work-cell and managing the production schedule. Vasic and Billard [7] mentioned that safety can be classified into two categories: the first, is physical safety and the second is psychological safety [8]. There are few methods in lean enterprise that concerns with employee safety. The methods are the 5S+1S and kaizen safety. For the 6S is the 5s famous method but adding an extra S for safety, the 6Ss are sort, set, sweep, safety, standardize and sustain[9].

2 METHODOLOGY

The research of the industrial robotics to be in the lean enterprise have a varied information

Retrieval Number: A00030681S519/19©BEIESP

Published By:
Blue Eyes Intelligence Engineering & Sciences Publication

all over the globe from research papers, the methodology to determine the current industrial robotics performance, which fit and compatible to the lean enterprise is to determine the performance measure of the industrial robotics the quality, cost, delivery, accountability and continual improvement (QCDAC). The method will measure each activity related to quality of products and waste elimination which industrial robotics contribute in this area due to their accuracy and fast technology level. Hence, lead to cut the cost of defects products and labor workforce, this is more expensive than industrial robotics which will also lead to delivery on time for product batches and that will lead to customer satisfaction alongside with accountability and continual improvement. Table 1 shows the QCDAC determination Principle [10].

Table 1: QCDAC Determination

No	QCDAC Principles	QCDAC Determination
1	Quality	Characteristic of features of service and product that is able to satisfy the given needs.
2	Cost	Optimize expenses to fulfill customer satisfaction.
3	Delivery	Delivery on time of product or service.
4	Accountability	Responsibility and commitment in achieving goals.
5	Continual improvement	On-going activities through teamwork in competing toward excellent performance.

Then after that the performance measures will be categorized by three lean principles which are flowing, pull and perfection, then identifying seven main categories to categorize the performance measures to get a detailed categorization and these categories are customer satisfaction, documentation process, employee involvement, employee training, information sharing, lead time and performance indicator. Then The final categorization it interacts the three elements that been mentioned, which are lean principles, QCDAC and the seven main categories, so each lean principle will use QCDAC to narrow down the performance measures and then the seven categories will identify the specific measures to be in this category. However, lean principles might not use all the seven categories it depends on the performance measures of the QCDAC. Then, using interpretive structural modelling (ISM) to rank the performance measures and identify the relationship among the performance measures according to six steps showed in Figure 1.

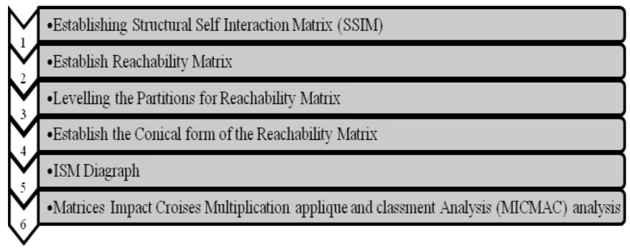


Figure 1: ISM Steps

3 RESULTS AND DISCUSSION

The determination of the performance measure depended on the QCDAC, lean principles and the seven-main category identified, in order to rank the performance measures in these categorizations the ISM method is used. The result shows the categorization and the ISM output of performance measure for the flow (quality). The first step of the ISM method is developing the structural self-interaction matrix to determine the relationship between performance measures according to this four latter which are V, A, X and O. The letter V is selected when performance measure I helps completing performance measure j, the latter A selected when performance measure j helps completing the performance measure I, the letter X selected when performance measure I and j completing each other and the latter O selected when performance measure I and j are not related, as shown in Table 2.

Table 2: SSIM Matrix

Variable j / Variable i	V7(LT)	V6(ET)	V5(DP)	V4(PI)	V3(EI)	V2(IS)	V1(CS)
V1(CS)	A	X	X	V	A	A	
V2(IS)	O	A	X	V	X		
V3(EI)	X	X	A	X			
V4(PI)	A	A	A				
V5(DP)	O	X					
V6(ET)	O						
V7(LT)							

The second step is to construct the reachability matrix according to the four latter in the SSIM matrix. If the relationship between (i and j) is V, then interaction between i and j is marked by 1 and (j and i) relationship marked by 0, if the relationship between (i and j) is A, then interaction between i and j is marked by 0

Retrieval Number: A00030681S519/19©BEIESP

Published By:
Blue Eyes Intelligence Engineering & Sciences Publication

and (j and i) relationship marked by 1, If the relationship between (i and j) is X, then interaction between i and j is marked by 1 and (j and i) relationship marked by 1 and if the relationship between (i and j) is O, then interaction between i and j is marked by 0 and (j and i) relationship marked by 0 as shown in Table 3.

Table 3: Reachability Matrix

Variable j / Variable i	V1	V2	V3	V4	V5	V6	V7
V1	1	0	0	1	1	1	0
V2	1	1	1	1	1	0	0
V3	1	1	1	1	0	1	1
V4	0	0	1	1	0	0	0
V5	1	1	1	1	1	1	0
V6	1	1	1	1	1	1	0
V7	1	0	1	1	0	0	1

The third step is to level the reachability matrix partitions, for every performance measure there are a reachability set, antecedent set and interaction set. The portioning level will happen if the reachability set and the intersection set are equal, then that would be considered as a level need to be partitioned. Then the selected level is removed from the table and the same method repeated until all the levels are partitioned. Table 4 summarizes the performance measures partitioning level, the first level is performance indicator, the second is customer satisfaction, the third is lead time, the fourth level contain two performance measures which are information sharing and employee involvement and the fifth level contain two performance measures which are documentation process and employee training.

Table 4: Reachability Matrix Partition

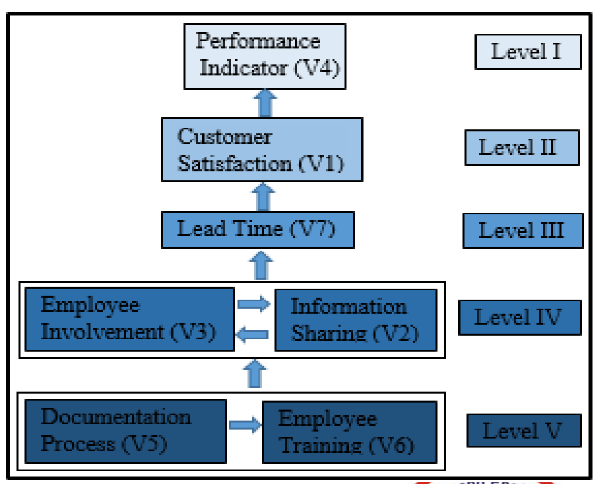
Performance measurement	Reachability Set	Antecedent Set	Intersection Set	Level
V1(CS)	1,4,5,6	1,2,3,5,6,7	1,5,6	II
V2(IS)	1,2,3,4,5	2,3,5,6	2,3,5	IV
V3(EI)	1,2,3,4,6,7	2,3,4,5,6,7	2,3,4,6,7	IV
V4(PI)	3,4	1,2,3,4,5,6,7	3,4	I
V5(DP)	1,2,3,4,5,6	1,2,5,6	1,2,5,6	V
V6(ET)	1,2,3,4,5,6	1,3,5,6	1,3,5,6	V
V7(LT)	1,3,4,7	3,7	3,7	III

The fourth step is to develop the conical form is required to arrange the reachability matrix according to the portioning level developed in the previous section to see the interaction of the performance measurements in different arrangement as shown in Table 5.

Table 5: Conical Form of Reachability Matrix

PM	V4	V1	V7	V2	V3	V5	V6
V4	0	0	1	1	0	0	0
V1	1	0	0	1	1	1	0
V7	1	0	1	1	0	0	1
V2	1	1	1	1	1	0	0
V3	1	1	1	1	0	1	1
V5	1	1	1	1	1	1	0
V6	1	1	1	1	1	1	0

The fifth step is constructed the SM diagraph, finalizing the reachability matrix and the portioning level, the structure of the model is generated and the interaction and relationships are identified. The ISM graph is a representation of the reachability matrix in terms of graph and converts it into the ISM model to clarify the ISM model output as shown in Figure 2.



Published By:
Blue Eyes Intelligence Engineering & Sciences Publication

Retrieval Number: A00030681S519/19©BEIESP

Figure 2: ISM Diagraph

The sixth step to identify the key factor of the performance measurements in terms of driving power and dependence power by classifying the analysis into four categories which are autonomous, dependent, linkage and independent, before categorising the performance measurers into these four groups [11]. The driver power and the dependence power need to be identified by the reachability matrix [12]. The driving power is determined by the number of ones in each row and the dependence power is the number of ones in each column as shown in Table 6.

Table 6: Determination of Driving and Dependence Power

PM	V1	V2	V3	V4	V5	V6	V7	Driving
V1	1	0	0	1	1	1	0	4
V2	1	1	1	1	1	0	0	5
V3	1	1	1	1	0	1	1	6
V4	0	0	1	1	0	0	0	2
V5	1	1	1	1	1	1	0	6
V6	1	1	1	1	1	1	0	6
V7	1	0	1	1	0	0	1	4
Dependence	6	4	6	7	4	4	2	

The linkage category has most of the performance measure for the flow (quality) which are customer satisfaction, information sharing, employee involvement, documentation process and employee training which mean that these variables has a strong driving and dependence power [13]. The dependent category has only one variable which is performance indicator which means that strong dependence power and weak driving power. The independent category [14] has one variable as well, which is the lead time in which it has weak dependence power and strong driving power as shown in Table 7.

Table 7: MICMAC Analysis

DRIVING POWER								
	7							
	6				5, 6		3	
	5				2			
	4	IV	7				1	III
	3							
	2							4
	1	I						II
		1	2	3	4	5	6	7
DEPENDENCE POWER								

The ISM model output showed that the performance indicator at the top level of the model in terms of flow (quality) which means that it has the most effect and reflects the other performances. The performance indicator of the industrial robotics is the most important measure to improve the quality and reduce waste.

5. CONCLUSION

The performance measures by QCDAC in which it outlined by three lean principles which are flow, pull production and continual improvement. The performance measures were listed after discussion with experts from the company and then categories in terms of the seven main categories which are customer satisfaction, information sharing, employee involvement, performance indicator, documentation process, employee training and lead time. Through ISM method the ranking of the performance measures achieved, the result showed the performance indicator as the most important measure in the model which concludes that the performance indicator of the industrial robotics in terms of flow (quality) is critical to support a lean enterprise to improve quality and reduce defects.

ACKNOWLEDGEMENT

The author would like to express his acknowledgement to sponsor of a fund due to the financial support throughout the period at which research was carried out. The Fundamental Research Grant Scheme (FRGS) is coded FRGS_12015TK03FKP02F00279.

REFERENCES

[1] J. Tasevski, M. Nikolić, and D. Mišković, "Integration of an Industrial Robot with the Systems for Image and Voice Recognition," Serbian Journal of Electrical Engineering, vol. 10, no. 1, pp. 219–230, 2013.

[2] Shakeel, P.M., Tolba, A., Al-Makhadmeh, Zafer Al-Makhadmeh, Mustafa Musa Jaber, "Automatic detection of lung cancer from biomedical data set using discrete AdaBoost optimized ensemble learning generalized neural networks", Neural Computing and Applications,2019,pp1-14.https://doi.org/10.1007/s00521-018-03972-2

[3] R. Ayres, "The impacts of industrial robots," Carnegie Melon Univ., vol. 1, November 1981, pp. 60, 1981.

[4] Shakeel PM, Baskar S, Dhulipala VS, Jaber MM., "Cloud based framework for diagnosis of diabetes mellitus using K-means clustering", Health information science and systems, 2018 Dec 1;6(1):16.https://doi.org/10.1007/s13755-018-0054-0

[5] D. Dimancescu, P. Hines, and N. Rich, The lean enterprise : designing and managing strategic processes for customer-winning performance. New York: American Management Association, 1997.

[6] A. Glaser, Industrial robotics: how to implement the right system for your plant automation, 1st ed. New York: ndustrial Press, Inc., 2009.

Published By:
Blue Eyes Intelligence Engineering & Sciences Publication

[7] M. Vasic and A. Billard, "Safety issues in human-robot interactions," 2013 IEEE Int. Conf. Robot. Autom., pp. 197–204, 2013.

[8] P. A. Lasota, G. F. Rossano, and J. A. Shah, "Toward safe close-proximity human-robot interaction with standard industrial robots," 2014 IEEE Int. Conf. Autom. Sci. Eng., pp. 339–344, 2014.

[9] A. Anvari, N. Zulkifli, and R. M. Yusuff, "Evaluation of approaches to safety in lean manufacturing and safety management systems and clarification of the relationship between them," World Appl. Sci. J., vol. 15, no. 1, pp. 19–26, 2011.

[10] E. Mohamad, "A Study on The Development Of Key Performance Indicators (KPIs) at an Aerospace Manufacturing Company," ResearchGate, vol. 2, no. 2, pp. 17, 2008.

[11] N. Sohani and N. Sohani, "Developing Interpretive Structural Model for Quality Framework in Higher Education : Indian Context," J. Eng. Sci. Manag. Educ., vol. 5, no. II, pp. 495–501, 2012.

[12] M. Zafarzadeh, "A Guideline for Efficient Implementation of Automation in Lean Manufacturing Environment," VOLVO GTO, 2013.

[13] J. P. Womack and D. T. Jones, "From Lean Production to the Lean Enterprise," Harv. Bus. Rev., vol. 72, no. 2, pp. 93–103, 1994.

[14] Baskar, S., Dhulipala, V.R.S., Shakeel, P.M., Sridhar, K. P., Kumar, R. Hybrid fuzzy based spearman rank correlation for cranial nerve palsy detection in MIoT environment. Health Technology. (2019). https://doi.org/10.1007/s12553-019-00294-8

Published By:
Blue Eyes Intelligence Engineering & Sciences Publication

Retrieval Number: A00030681S519/19©BEIESP