Discovering the Readiness of Malaysian Industry in Adaptation of Industrial Revolution 4.0 towards Manufacturing Sustainability

M.N.H.M. Rosdi, M.R. Muhamad, W.H.W. Mahmood, M.H.A. Kadir

Abstract: ***Industrial revolution 4.0 is hitting manufacturing industry where a big amount of data and equipment are being introduced. There are many definition of IR 4.0 defined by researchers and industrialists from the whole world. Some of the popular definition are customization, digitalization, flexible, responsiveness and automation. This paper will focused only on one element of IR 4.0 which is responsiveness. Responsiveness holds an essential role in IR 4.0 where manufacturing firms have to be responsive on the whole manufacturing process related with their business from the production design, planning, customer, society, surrounding, technology, suppliers and stakeholders. On the other hand, lots of issues related with sustainability are arise either from governed authority or non-government bodies. This issue is very sensitive and should be considered by manufacturing firms in any decision made. This scenario makes IR 4.0 and sustainability looked moving in the opposite direction where achieving and competing in IR 4.0 will make manufacturing firms neglecting the sustainability issue. In order to be more sustainable in this industry, manufacturing firms should consider to be responsiveness and its impact towards manufacturing sustainability. This research started with finding the key manufacturing responsiveness and sustainability practices and elements from the published articles. Then, a structured questionnaire survey is constructed thus distributed to reachable manufacturing firms in Malaysia. The data gathered is analyzed using SPSS software on the data reduction and factor analysis, Cronbach's alpha reliability test and Pearson correlation. The result proved that Malaysian industry is very well aware and prepared regarding manufacturing responsiveness and sustainability as well as manufacturing management. When analyzed deeper, research found that Malaysian industry is lack or considered weak in competitiveness thus it is essential in future to focus on this area.***

Keywords: ***Industry revolution 4.0, manufacturing responsiveness, manufacturing sustainability***

Revised Manuscript Received on November 19, 2019

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I. INTRODUCTION

This section concentrated on current situation and certain concepts that are adapted and implemented in this research. The flow started with a brief discussion on Industry 4.0 (IR 4.0) before narrowed down the scope into manufacturing responsiveness (MR) as one of essential element in Industry 4.0. In this research, MR practices act as independent variable in discovering its interaction or impact on manufacturing sustainability (MS) which is dependent variable. Lastly, literature on MS is extracted where it has a further well-known classification environmental, economical and social sustainability.

A. Industrial Revolution 4.0

IR 4.0 has been an influence factor in manufacturing industry where most manufacturing firms have been chasing towards it. There are several terms to define IR 4.0 according to published articles. IR 4.0 emphasizes the usage of internet connection, high end technology and digitalization to meet customer requirements [1]. Wang [2] expressed that IR 4.0 is leveraging various elements in manufacturing namely IT based communication, tools, machines, IT interaction services and products. Wang [2] also divided IR 4.0 into four components which is cyber physical system, mobile and cloud computing internet of thing (IoT), big data and knowledge discovery, and internet of services (IoS). From other perspective, IR 4.0 consisted of four aspects: (1) factory, (2) business, (3) products and (4) customers where these aspects expressed as the main vision in any manufacturing firms [3].

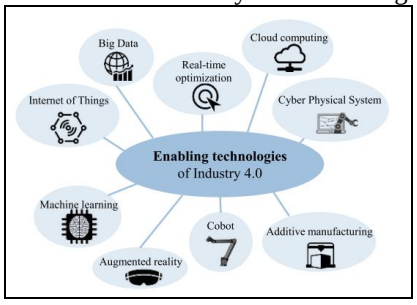

Fig. 1: Enabling Technologies of IR 4.0 [1]

Figure 1 listed all the related essential technologies to be integrated in achieving IR 4.0.

By all the IR 4.0 components, definitions and technologies, the main objective is fulfilling customer demands. The market and customer requirements that keep changing with lots of variety and customization need every manufacturing firm to be responsive [4]–[6]. It can be

clinched that one of the main outcome of IR 4.0 is to be a responsive manufacturing firm. Manufacturing responsiveness here not only limited to customer oriented [1], [6], it also included supply chain responsiveness [5], responsive manufacturing system [2], responsive to market trends changes [7] and responsive towards quick changeover [3]. There are various manufacturing responsiveness perspective thus categorized it will give a valuable input into this field.

B. Manufacturing Responsiveness

In this research, MR appears to be a variable that represent IR 4.0. As stated earlier, MR covers a wide range of manufacturing phase from supplier until customer. Table 1 summarized the MR areas that have been highlighted by published research.

Table-I: Highlighted Manufacturing Responsiveness Area

NO	AREA	REFERENCE
1	Customer/Market	[8]–[11]
2	Supply Chain	[12]–[16]
3	Production Line/Operation	[9], [17], [18]
4	Product	[11], [13]
5	Organization/Human Management	[18]–[22]

In general, [18] defined MR as overall property including human resources and machines that react to external changes especially which that will give disturbance to their current manufacturing system. It is clear that MR scope not only limited to machines and technology but also human resources.

C. Manufacturing Sustainability

Manufacturing sustainability is a crucial circumstances where all manufacturing firms struggling to achieve. Besides the rapid improvement of technology, MS should not be neglected to ensure the continuity of business [23]. MS has been discussed widely by lot of research made, thus it has its well-known three components namely environmental sustainability (SE), economical sustainability (SN) and social sustainability (SC) [23]–[25]. The importance of MS in IR 4.0 also has been improvised by Morrar [7] in a framework as shown in Figure 2. Figure 2 concluded the importance of MS as it also visualized as one of the mission in IR 4.0. Roberts & Ball (2014) has developed a library of manufacturing sustainability practices to be adapted by other research. The importance of MS in manufacturing industry as well as committing to IR 4.0 environment drive this research

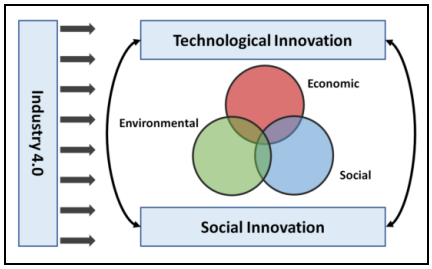

Fig. 2: Framework of Sustainable Industry 4.0 [7]

to discover the interaction of MR as an element of IR 4.0 with respect to MS represented by SE, SN and SC.

II. METHODOLOGY

This research started with cross reference research articles from 2008 until 2017 on IR 4.0, MR and MS as implemented by Mohd Rosdi et al. (2016) where matrix form developed to systematically review all related literature on specific field. The review has come out with 18 elements of MR practices and 10 practices each for SE, SN and SC as an initial elements to be included in the questionnaire survey. The questionnaire survey implemented five Likert scale as respondents agreement with the practices listed. A total of 200 sets of questionnaire survey have been distributed by mail, e-mail and by-hand, only 51 were returned. Thus the responds is analyzed using software IBM Statistical Package for Social Science (SPSS) with the chosen three analysis: (1) Data reduction and factor analysis (2) Cronbach's Alpha reliability analysis and (3) Pearson Correlation analysis. The result obtained from these analyses will be used to construct a framework represent the flow of IR 4.0 or MR adaptation towards MS particularly in Malaysian industry.

III. RESULT

A. Data Reduction and Factor Analysis

This analysis is proposed to eliminate and classify the elements consisted in the questionnaire survey distributed. The pattern of data gathered from all the respondents could determine both insignificant elements and then classify the elements within a group into several sub classifications. Before decided to eliminate and classify the elements, the value of Kaiser-Meyer-Olkin (KMO) measure must be greater than 0.6 and Significant (Sig.) Less than 0.05 in KMO and Bartlett's Test. In eliminating any element, there are two main point which needed to be examined in detail which are bi-factor element and low factor loading (less than 0.5) [28]. Lastly, it is essential to recheck the Cronbach Alpha Reliability value to be greater than 0.6.

Concentrated back to this research, all the main components namely manufacturing responsiveness (MR), environmental sustainability (SE), economical sustainability (SN) and social sustainability (SC) are undergone this data reduction and factor analysis. The result of MR is shown in Table II below.

Table-II: Data Reduction and Factor Analysis for Manufacturing Responsiveness

	CLASSIFICATIONS		
	INTERNAL	COMPETITIVE	INNOVATION
KMO MEASURE = 0.794 SIG. = 0.00	MR5 MR11 MR14 MR15 MR18	MR4 MR7 MR17	MR2 MR8 MR9 MR10
	CRONBACH'S ALPHA = 0.807	CRONBACH'S ALPHA = 0.788	CRONBACH'S ALPHA = 0.787

Table II shows that the analysis has eliminated six out of 18 elements in manufacturing responsiveness; MR1, MR3, MR6, MR12, MR13 and MR16. MR1 and MR16 were eliminated due to insufficient element in a classification resulted from factor analysis. The ideal number of element in a classification should be at least three. The other four elements were rejected reflected from low factor loading (smaller than 0.5). These circumstances left

only 12 elements where factor analysis classified them into three namely internal responsiveness, competitiveness and innovation. The elements lied on those three classifications are as listed in Table II.

Next components to be undergo the analysis is manufacturing sustainability. As widely known and studied done on MS, it cannot be separated with its three components; SE, SN and SC. The analysis also will be done by these three segregations starting with SE, SN and lastly SC where each come with 10 elements initially. Table III shows the result on SE.

Data reduction analysis only eliminated one element of SE which is SE4. As stated in Table III, there are two classifications of SE where suited to be entitled as controlling and avoiding environmental pollution. SE5, SE6, SE7, SE8, SE9 and SE10 listed under controlling while SE1, SE2 and SE3 listed under avoiding. Table IV represent the result for the second MS component (SN) while Table V represent the last SC as the last MS component.

Table-III: Data Reduction and Factor Analysis for Environmental Sustainability

	Classifications	
	Controlling	Avoiding
KMO Measure = 0.804 Sig. = 0.00	SE5 SE6 SE7 SE8 SE9 SE10	SE1 SE2 SE3
	Cronbach's Alpha = 0.927	Cronbach's Alpha = 0.710

Table-IV: Data Reduction and Factor Analysis for Economical Sustainability

	Classification
	Economical
KMO Measure = 0.68 Sig. = 0.00	SN1 SN5 SN6 SN7 SN8
	Cronbach's Alpha = 0.802

Table-V: Data Reduction and Factor Analysis for Social Sustainability

	Classification
	Social
KMO Measure = 0.886 Sig. = 0.00	All SC1 – SC10
	Cronbach's Alpha = 0.939

Both Table 3 and Table 4 have similar table pattern where factor analysis classified them only into a single classification. The classification named as the original components which are economical and social sustainability. Detail view on Table 3 discovered that only five elements left out of ten. SN elements that are accepted here are SN1, SN5, SN6, SN7 and SN8. Only SN4 eliminated by poor factor loading while the other four had to be left because insufficient number of element in a classification. Lastly, data reduction and factor analysis on SC resulted as the most reliable with highest KMO measure among four components that undergone the analysis. SC also seems to be the best component by the acceptance of all its 10 elements in factor analysis and holds the highest reliability Cronbach's Alpha value with 0.939.

B. Highlighted Correlation between Manufacturing Responsiveness and Sustainability

All responds are analyzed by Pearson's correlation analysis. Correlation analysis is important in order to determine which independent and dependent variable have significant similar reaction or relate tightly among them. Usually most of them will have a positive correlation where this research will be highlighted on the top of the cream. Table VI will simplified the result for Pearson correlation.

The result from Pearson correlation on this research elements giving most of them correlate positively each other. There is only one relation is negative but it is not significant (-0.032 between MR7 and SN9). The result of Pearson correlation is divided into positive or negative correlation, significant correlation ($0.01 < Sig. \leq 0.05$) and strongly significant correlation ($Sig. \leq 0.01$). Table 5 listed all MS elements with strong significant correlation corresponding to MR elements. The distribution of MS elements from Table 5 clearly resulted on competitive responsiveness not really has significant correlation with MS supported by none from SE and SC has strong significant correlation with MR7 (consider investment trade off).

Table-VI: Summary of Pearson's Correlation Analysis

Manufacturing Responsiveness		ELEMENTS WITH SIGNIFICANT AT THE 0.01 LEVEL		
		Environmental Sustainability	Economical Sustainability	Social Sustainability
Internal	MR5	SE5, SE6, SE7	SN6, SN8	SC2, SC9
	MR11	SE3	SN1, SN5, SN6, SN7, SN8	SC2, SC5, SC9, SC10
	MR14	SE1, SE3, SE6, SE7, SE9, SE10	SN2, SN3, SN5, SN6, SN7, SN8	SC1, SC2, SC3, SC4, SC5, SC7, SC8, SC9, SC10
	MR15	SE5, SE6, SE7, SE9, SE10	SN2, SN3, SN5, SN6, SN7, SN8	SC2, SC3, SC4, SC5, SC6, SC7, SC8, SC9, SC10
	MR18	SE5, SE7, SE8, SE9, SE10	SN1, SN5, SN6, SN7, SN8	SC2, SC3, SC4, SC5, SC6, SC7, SC8, SC9, SC10
Competitive	MR4	SE6, SE7, SE8	SN6, SN7, SN8	SC6
	MR7		SN7	
	MR17	SE2, SE7, SE8	SN7, SN8	SC6, SC7, SC8, SC10
Innovation	MR2	SE2, SE7, SE8, SE10		SC8
	MR8	SE1, SE2, SE5, SE6	SN7, SN8, SN9, SN10	SC5, SC9, SC10
	MR9	SE5, SE6, SE7, SE8, SE10	SN2, SN6, SN8, SN9	SC1, SC2, SC3, SC5, SC8, SC9, SC10
	MR10	SE2, SE3, SE5, SE6, SE7, SE8, SE10	SN1, SN2, SN6, SN7, SN8	SC2, SC5, SC8, SC9, SC10

*** Elements in red represent the highest correlation value with the corresponding manufacturing responsiveness element**

It is quite hard when comparing between community and information responsiveness but when listed according to MR elements, MR2 (redesign production line for new product) none correlate significantly with SN. The result may interpreted differently from the other perspective, where SN6 (minimize transportation cost) lead others with three times held the highest correlation value; MR5 (use new resources), MR11 (treated all department similarly) and MR14 (adequate support). This ranking followed by SE2 and SN8 where both elements appeared top twice.

In next section, the summary of both results are discussed which this research will suggested an info-graphic summary to make it more understandable.

IV. DISCUSSION

This research consists of two main components; IR 4.0 and MS. IR 4.0, which is represent by MR as one of its pillar or essential element acted as independent variable while MS represent by its well-known subcategories (SE, SN and SC) acted as dependent variable in this research. It is MS that desired to be achieved while adapting the MR culture or practices. By considering all analysis done, Figure 3 suggested as the conceptual framework of MR adaptation towards MS.

All accepted elements for MR is included in the framework where the size of internal responsiveness, innovation and competitiveness slightly decreasing based on the number of sub-elements and the number of significant correlation with SE, SN or SC. It suggested that priority should be in sequence from internal responsiveness, innovation and lastly competitiveness. From MS side of view, all SE, SN and SC should be treated similarly as literally all these three components held the same weightage towards overall manufacturing sustainability.

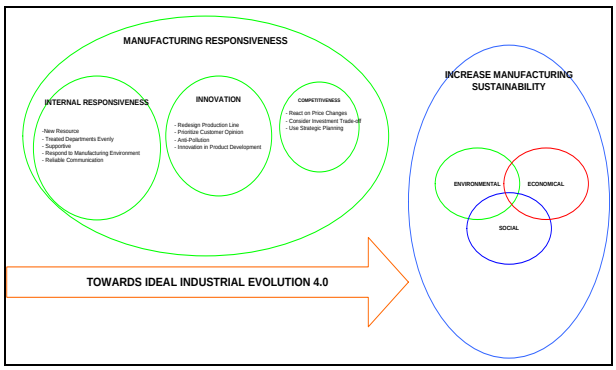

Fig. 3: Conceptual Framework of Manufacturing Responsiveness Adaptation towards Manufacturing Sustainability

V. CONCLUSION

This research come out with three main conclusion; (1) As an enabler for IR 4.0, MR has three components namely internal responsiveness, innovation and competitiveness. All these components appeared evenly but when correlate with MS, it has shown different reaction. (2) MS is considered as an important mission in manufacturing industry specifically in Malaysia because it can be concluded that all MS elements has positive correlation with MR and lastly (3) Malaysian industry still lack in competitive environment which it might due to several reasons that undiscovered in this research. As suggestion, further analysis need to be done with the data to ensure that the assumptions and suggestions are reliable to be adapted in real industry practice or to be implemented by researchers.

ACKNOWLEDGEMENT

This research is co-funded by Majlis Amanah Rakyat (MARA), University Technical Malaysia Malacca (UTeM) under grant (FRGS/2016/FTK-AMC-/F00324) and MyPhD under Ministry of Education.

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