DISCOVERING THE CLASSIFICATION OF MANUFACTURING COMPLEXITY FROM MALAYSIAN INDUSTRY PERSPECTIVE

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ABSTRACT: Nowadays, manufacturing complexity (MC) is considered as a major challenge in manufacturing industry. MC covers a very wide area in manufacturing practices either within firm's control or out of control, either directly or indirectly with manufacturing routines. As the technology and globalization getting better, the challenges born by MC are also getting tougher. This scenario experienced by worldwide manufacturing firms including Malaysian manufacturing industry. In order to face this challenges, it is essential to manage MC accordingly. Although some researchers expressed MC negatively, it is believed that managing MC in correct manners will be beneficial to manufacturing firms. The first step towards managing MC accordingly is knowing MC itself in every angle. Generally, MC is divided into two division which are internal MC (IM) and external MC (EM). Initially, both division have several elements which the numbers are 30 and 22 elements for IM and EM, respectively. A set of questionnaire survey consisting of these elements has been distributed to representative of manufacturing firms across Malaysia to gather the information and through factorial analysis using Statistical software (SPSS), these elements are classified into smaller number of classification to facilitate towards the better MC management. The classifications for IM are human management, production design, productivity, job floor management and conflicts while for EM are local culture, trend changes, volume variety and globalization. These classifications will support industrialist especially in Malaysia towards better MC management to grow a better outcome in manufacturing industry.

KEYWORDS: *Manufacturing Complexity; Internal Manufacturing Complexity; External Manufacturing Complexity; Factorial Analysis*

1.0 INTRODUCTION

As industry 4.0 is approaching and expanding, the whole manufacturing practices and routines also need to be reform to a better responsive and sustainable manner [1]. This is very important in ensuring the industry may give a positive impact on its surrounding which are personnel, organizations, community, environment and future generation. The expanding movement in technology impacted positively and negatively refers to the different perspective point of view. All this scenario combination and connection, with addition with unusual and unavoidable manufacturing uncertainty is called MC [2-3]. Related with industry revolution 4.0 as stated earlier, as the revolution revolved, more manufacturing components need to be considered in all level of decision making. These scenario required a relationship among big components which perhaps increasing MC level to be solved by manufacturing practitioners [4].

MC is an entity that will be faced by all manufacturing firms. Either realized or not, industrialist around the globe are facing MC. Thus, it is emerged to immediately manage MC in a proper way. Dedicated towards the MC management purpose, the objective of this research is to classify MC elements in Malaysian industry into several groups where it would facilitate industrialists in MC management.

1.1 Manufacturing Complexity

Manufacturing complexity is an obstacle that manufacturing firms need to manage as it is being ranked the first enemy for manufacturing firms which reacted as a border between successful and failure in industry [5]. This is because globally the perception on MC is in a negative way as expressed by Macchion et al. [6] and Hu et al. [7]. MC is spreading across the firm internally and externally. With this spreading behavior, MC will impacted on manufacturing performance and outcomes. On top of that, MC also can also be impacted positively if being properly managed. There are various definition of MC referred to various background of researchers. Among the highlighted description on MC is by two words, predictable and unpredictable [8]. A previous framework classified MC into production strategy (manufacturing area; scheduling management; and supply chain management) and human management (Personnel self-assessment; and organizations' transformation). The other picture of MC is it consists of interrelationship among all resources and information which stated that the bigger firm with higher level of resources and information experienced greater MC [4]. The resources and information refer to a lot of elements for example employee, supplier, customer, machines, building and knowledge.

In order to manage MC in proper way, it is essential to completely understand the MC itself and the parameters involved. Towards this proper management, there are six main descriptions of MC stated by numbers of researchers worldwide. The most relevant and clear description of MC is the division of MC into internal and external manufacturing complexity [9-10].

This description also is the most agreed description among researchers as expressed in articles. In addition, managing MC also will be a lot easier by divided MC into IM and EM because it clearly distinguish the controlling entity on them [10].

1.2 Internal Manufacturing Complexity

Internal manufacturing complexity covers manufacturing activities that happen inside the firm and any practice or routine within firms' control [11, 15]. There are a lot of obvious example for IM namely employee, machine, production process, material handling system and inventory [12-13]. Manufacturing firm owned them thus have the right to control and use them as desired. Logically, IM should be lot easier to be managed compared to EM because the authorization is within the respective managerial level. Table 1 lists all elements of MC both IM and EM.

Table 1: The elements of manufacturing complexity

Items	Internal Manufacturing Complexity (IM)	Items	External Manufacturing Complexity (EM)
IM1	Implement better capacity planning	EM1	Globalization of customer
IM2	Implement job scheduling	EM2	Size of customer
IM3	Reduce production time	EM3	Changes of product architecture by customer
IM4	Reduce production cost	EM4	Demand variability in volume
IM5	Implement facility layout planning	EM5	Customer trend changes
IM6	Improve logistics and distribution	EM6	Acceptance of variability in product quality such as function, lifespan and etc.
IM7	Improve quality inspection process	EM7	Action of competitor
IM8	Usage of machine and equipment	EM8	Standards and regulation by authority
IM9	Quality inspection equipment	EM9	Globalization of supplier chain
IM10	Sufficient and effective employee training	EM10	Incompetent supplier
IM11	Information flow management	EM11	Size of supplier
IM12	Interdepartmental conflict	EM12	Market trend changes
IM13	Existence of personal conflict	EM13	Product lifespan
IM14	Fulfilling key performance index (KPI)	EM14	Company reputation
IM15	Increase sales and revenues	EM15	Availability of skillful workers
IM16	Managing employees behavior	EM16	Expectation of secondary stakeholder
IM17	Capability of top management	EM17	Variety of product
IM18	Improve organization's culture	EM18	Variety of machine required
IM19	Material handling system	EM19	Implementation of flexible manufacturing system
IM20	Improve production planning	EM20	Manufacturing uncertainty
IM21	Inventory management	EM21	Needs to control environmental pollution
IM22	Manage production records system	EM22	Needs to use user friendly machine/equipment
IM23	Establish standard operation procedure (SOP)		
IM24	Documentation approval system		
IM25	Improve quality assurance		
IM26	Maintenance management		
IM27	Vendor selection process		
IM28	Needs to use simulation		
IM29	Needs to implement reengineering		
IM30	Improve customer relation		

1.3 External Manufacturing Complexity

External manufacturing complexity involves all elements that not within manufacturing firms' charge [5]. This concluded all elements that not in charge by manufacturing firm are included in EM. The example is customer, supplier, competitor, authority rules and regulations, and secondary stakeholder. Even though customer and supplier seems very close to the firms, they are considered EM because the firms have no right to make them follow their needs and command.

2.0 METHODOLOGY

This research is conducted with development of a set of questionnaire survey consisted of the demographic and firm information, 22 elements of EM and 30 elements of IM. The elements constituted with EM and IM extracted from various research articles regarding MC from 2004 till present. The survey used Likert-scale from scale '1–5' which represent the rate of agreement with the statement with 1- strongly disagree, 3-neutral and 5-strongly agree [1]. The questionnaire is targeted for a representative from each manufacturing firm in Malaysia with the minimum of one year experience in that particular firm. This is to ensure that the representatives have understand the firms' culture. Among a total of 200 sets of survey that have been distributed, only 51 returned with complete response which represents 25.5% from the total target respondent.

The data gathered undergo several analysis using statistical package for social science (SPSS) as a tool to achieve the objective of the research. The analysis involved are descriptive analysis, reliability analysis, data reduction and factor analysis. The analysis performed are sufficient to discover the classification of MC from Malaysian industry perspective.

3.0 RESULTS AND DISCUSSION

3.1 Demographic Information

The demographic data is important as representation of the respondents' population. Demographic data also is useful to develop research scope and limitation. The size of the industry is essential in this research because the bigger the size, the greater the MC should be in the firm where the classification is based on SME Corporation in Malaysia [14]. Figure 1 shows the result.

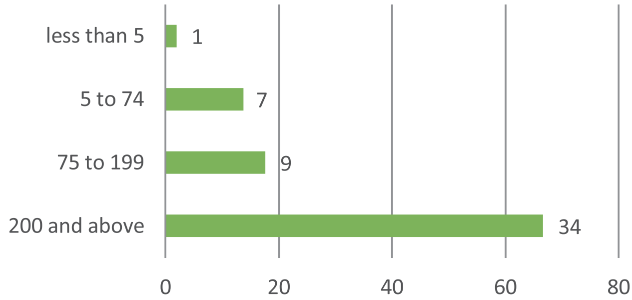

Figure 1: Number of employees

The data shows that 66.67% or 34 respondents represent the large industry with the number of fulltime employee greater than 200 persons followed by medium industry with 17.65% or 9 firms. Looking into the industry product group, the population shows 19.6% from automotive industry, 13.7% from petroleum and chemical based industry, while the others shows a small number which are below 10% population namely food and beverages; rubber, plastic and non-metal; computer, electronic and optical and machinery and equipment with 9.8% followed by electrical equipment with 7.8% and aerospace and metal with 5.9%. The smallest population is from wood and furniture product group with only 3.9%.

3.2 Reliability Analysis of the Main Variables

Reliability analysis is conducted to ensure the consistency of the measures used on the elements or variables involved. Cronbach's alpha coefficients reliability test is used in this analysis. Table 2 shows the values of Cronbach's alpha for EM and IM.

Table 2: Cronbach's alpha

No	Questionnaire Components	Abbreviation	Cronbach Alpha, α
1	External Manufacturing Complexity	EM	0.895
2	Internal Manufacturing Complexity	IM	0.935

Both variables have the Cronbach's alpha values greater than 0.7 which are 0.895 and 0.935 for EM and IM respectively. Thus, it can be concluded that the measures have an acceptable level of reliability. The measures are considered to have sufficient level when the Cronbach's alpha value is equal or greater than 0.7.

3.3 Data Reduction and Factor Analysis on Manufacturing Complexity

Factor analysis is done to classify the number of latent factors underlying the respondents respond pattern through questionnaire survey collected and divided into several smaller classifications [15]. Through this analysis, the elements with bi-factorial element or/and low factor loading will be eliminated in order to come out with a firm classification. All the elements undergo the correlation analysis. This is to ensure all elements are significant and none has multi-collinearity with correlation value greater than 0.8. Next, the remaining elements (if eliminated any) will undergo Kaiser-Meyer-Olkin (KMO) and Bartlett's test. The KMO need to pass the acceptable level which is 0.6 while Bartlett's test should be significance before accepting the classification produced by the factor analysis. This steps are repeated until no more bi-factorial element and low factor loading. Table 3 shows the summary of factor analysis done on IM.

Table 3: KMO and Bartlett's test for internal manufacturing complexity

Trial	KMO measure for sample adequacy	Bi-factorial element	Low factor loading	Item deleted
1	0.741	IM17,24,25	IM24	IM24
2	0.755	IM17,25	IM17,25	IM25
3	0.745	IM17,26,27,29	-	IM29
4	0.744	IM7,17,20,26	-	IM26
5	0.743	IM7,17,20	-	IM7
6	0.758	IM1,17,20	IM1	IM1
7	0.739	IM17,20	IM20	IM20
8	0.739	IM17	-	IM17
9	0.716	IM30	-	IM30
10	0.736	-	IM6,8,15,27	IM6,8,15,27

Factor analysis is done on IM with 10 trial before producing with a reliable and firm set of classifications. Through the process, 10 trial of factor analysis has been done with 13 elements have been eliminated. The eliminated elements based on sequence are IM24, IM25, IM29, IM26, IM7, IM1, IM20, IM17, IM30, IM6, IM8, IM15 and IM27. This resulted on only 17 elements left in IM variables. Even though the eliminated elements nearly reach 50% of the total elements, the result will be more accurate rather than having a lot of conflicted elements. The significance p-values are 0 for all trial which shows that all trials done during the reduction factor analysis are significance where the remark value should be less than 0.005. Table 4 presents the classifications produced by the factor and reliability analyses.

Table 4: Cronbach's Alpha Reliability test for internal manufacturing components

Components	Classification	Items	Cronbach's alpha
1	Human Management	IM10,11,14,16,18,23	0.879
2	Production Design	IM19,21,22,28	0.821
3	Productivity	IM3,4,9	0.773
4	Job Floor Management	IM2,5	0.670
5	Conflicts	IM12,13	0.747

Among 17 elements in IM, the analysis produced five components or classifications. The classification names are based on the nature of the elements consist within them. The classification with related elements are: 1. Human management: IM10, IM11, IM14, IM16, IM18 and IM23; 2. Production design: IM19, IM21, IM22 and IM28; 3. Productivity: IM3, IM4 and IM9; 4. Job floor management: IM2 and IM5 and 5. Conflicts: IM12 and IM13. Even though the forth classification which is job floor management come out with Cronbach's alpha value of 0.67 which is less than 0.7, the elements still can be considered to be included in the classification because both elements do not have conflicted bi-factorial elements and acceptable factor loading based on data reduction and factor analysis done. These five classification represent the whole IM particularly in Malaysian manufacturing industry. The first classification named 'human management' involved with the biggest number of elements which is six elements including employee training, information flow, key performance index, human behavior, organization culture and establish standard operation procedure. This finding strengthen the theory that human characteristics are the most important and have higher impact on organization's performance outcome. Human also considered as the most complex creature on earth to be managed and yet human also is the most valuable asset a firm has.

The second rank is 'production design' that consists of four elements namely material handling system, inventory management, production records management and simulation implementation. These elements covers the production floor management and more towards the implementation routine on the production. Production design clearly will be the second ranked classification because it will determine the direct production practiced done by human. Table 5 shows the summary of factor analysis done on EM.

Table 5: KMO and Bartlett's test for external manufacturing complexity

Trial	KMO measure for sample adequacy	Bi-factorial element	Low factor loading	Item deleted
1	0.678	-	EM9,14	EM2,9,10,13,14,15

Unlike IM, EM seems gave clearer classification based on questionnaire responds. Only one trial needed to produce the desired classes. Among 22 elements, there are six elements being eliminated which are EM2, EM9, EM10, EM13, EM14 and EM15. The result leaves 16 elements for EM for further analysis. Table 6 presents the classification produced by factor analysis for EM.

Table 6: Cronbach's Alpha Reliability test for external manufacturing components

Components	Classification	Items	Cronbach's alpha
1	Local Culture	EM6,8,16,18,19,21,22	0.848
2	Trend Changes	EM5,7,12,17	0.836
3	Volume Variety	EM4,11,20	0.632
4	Globalization	EM1,3	0.609

The result gave four classifications from the 16 elements left in EM which being named as local culture, trend changes, volume variety and globalization. Amongst them local culture hold the biggest number of elements consisting EM6, EM8, EM16, EM18, EM19, EM 21 and 22 which are product variety acceptability, authority standards and regulations, secondary stakeholders expectation, machine variety, flexible manufacturing system implementation, environmental pollution control and user friendly machine requirement. Local culture is a factor that is considered as main matter that manufacturing firms need to consider and deal with upon deciding to open a manufacturing plan or sub plan in certain area. Not all local culture is bad, but the people around who will be the employees of the firm need to follow the culture that suits towards firms' vision and mission.

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Similar with the classifications in IM, all four classifications in EM are reliable. Their Cronbach's alpha values are above 0.6 ranging from 0.609 to 0.848. As mentioned above, even though two of the classifications have the Cronbach's alpha value less than 0.7, the classifications are still included due to non bi-factorial elements, acceptable factor loading and the value of 0.6 and above is accepted as eliminating these elements may make the classification simple and less impacted. It concludes that the classifications come from the factor analysis for both IM (human management; production design; productivity; job floor management; and conflicts) and EM (local culture; trend changes; volume variety; and globalization) are best representing MC based on Malaysian industry perspective particularly and worldwide generally.

Comparing the finding with other research that related with manufacturing management during rapid industry revolution era, the research scope would be narrowed and grouped into the critical area that problematize the firm. For example, a research in employee training and information flow could be done together especially in Malaysian industry where both of them classified under the same sub-classification. This research may suggested that these two research which are; document control approval process and product development to be combined together because from the finding, both areas lied in the same class [16].

4.0 CONCLUSION

The main objective of this research is achieved where manufacturing complexity is best to be divided into two main components which are internal manufacturing complexity and external manufacturing complexity. These two main classifications will provide clear controlling power and knowing which complexity element can be self-manage and which complexity is out bounce from firms' manageability. The questionnaire survey conducted in Malaysia resulted in a detail sub-elements and the associated classifications. The classification is useful for manufacturing firms especially in Malaysia to know the specific areas needed to be managed properly. Besides that, the classification also may be implemented or verified at other country as this research is only done in Malaysian manufacturing industry. The result may be the answer for researchers

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