Industrial Types of Manufacturing Complexity

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Abstract – **This paper is prepared to disclose the types of manufacturing complexity for just over a half of hundred manufacturing companies in Malaysia. Complexity was claimed has negative correlation with productivity. The manufacturing complexity is divided into six categories; manufacturing system design, inventory management, supply chain management, human resource and job design, quality management system and project management. The results show that there are various types of manufacturing complexity in different industries. However, most of manufacturing complexities are not significance with product characteristics, company main business operation, process type, layout, and operation system.**

Keywords – **Manufacturing Complexity, Manufacturing Industries**

I. INTRODUCTION

Nowadays, most of companies in the world are looking the best ways in improving productivity. However, there are many factors that influence the productivity reduction. One of the factors is complexity. In this paper, the concept of complexity is considered for unneeded complexity which has negative correlation with productivity.

Complexity is defined as the opposite of simplicity. Complexity in specific usage is the opposite of independent while complicated is the opposite of simplicity.

Until now, the term complexity has no satisfactory and generally admitted definition. It is basically discussed in connection with the system theory and is referred to as a system attribute. A system consists of elements or parts (objects, systems of lower order, subsystems) and the existing relationships between them. It is also agreed that a system should perform a specific function and has to be well distinguished from its environment without confusion.

The complexity of a system is defined with respect to the complexity variables, namely number, dissimilitude and states' variety of the system elements and relationships. These variables enable one to make the distinction between static and dynamic complexity. Whereas static complexity describes the system structure at a defined point in time, dynamic complexity represents the change of system configuration in the course of time. For example, by considering the product arrangement system which consists of the functional and building oriented subsystems of the production program, all possible product variants that can be manufactured at a point in time determine the static system complexity. However, the dynamic complexity is determined by the frequency and magnitude of changes of the product arrangement system when new product variants are introduced or eliminated [1].

On the basis of the structural and dynamic complexities, Underwood [2] has determined taxonomy for system complexity. When both complexities are low, then the system is simple. In the case of a high (low) structural complexity and low (high) dynamic complexity, the system is considered to be complicated (relatively complex). When both complexities are high, then the system is said to be extremely complex. Low complexity is predictable while high complexity is unpredictable.

Manufacturing is the process of adding value to a material to build a product [3]. The art of manufacturing implies a process, or some repetitive sequence of operations, used to build the product. Manufacturing requires resources to produce the product, including an infrastructure of people in an organisation providing the necessary support for manufacturing.

Tanner [4] stated that manufacturing engineering is specified knowledge and skill in engineering science and analysis applied to the design, operation, and control of manufacturing processes and systems. Included in this broad definition are the following primary activities:

1). Selection and design of manufacturing process
2). Determination of sequences and methods for product fabrication, assembly and test.
3). Selection and design of production equipment
4). Selection and design of tools and test equipment
5). layout of factory buildings, machines, equipment, materials and storage facilities
6). determination of standard times for manufacturing operations
7). selection and design of manufacturing systems and computer-aided manufacturing techniques
8). manufacturing cost estimating, cost analysis, and cost trade studies
9). manufacturing research and development

10). review of product designs and specifications to ensure manufacturing productibility
11). management, coordination, and control of manufacturing operations

This paper is an initial study (pilot study) on the relationship between manufacturing activities and complexity in Malaysia. It aims to discover the types of manufacturing complexity existed in manufacturing industries and the significance factors that influence the complexity based on complexity theory. The following sub-title will describe the data collection method, validation of the result, result, discussion, and conclusion which can be referred by other companies to define their complexity and other academician to explore what can be improved in complexity studies towards simplicity.

II. DATA COLLECTION AND VALIDATION

For data collection, postal questionnaire survey was performed. The surveys were addressed to production managers for over 300 companies in Malaysia. Sampling technique is not used because the survey not representing any population. The other reason is that, this study is only an initial study in manufacturing complexity in Malaysia. Yet, only just over a half of hundred companies representative had responded. As a result, only 56 completed questionnaires were used to analyse. For validation, the *Cronbach Alpha* value, 0.980 shows that the answers in questionnaire survey are high reliability.

III. RESULT & DISCUSSION

The data were analysed by using SPSS programming. Descriptive statistics such as frequency, percentage, mean, standard deviation (sd) are main statistical analysis. In addition, Chi Square Test was performed to identify the significant level between types of manufacturing complexity against industrial operation system which included product characteristics, type of industry, main business operation, process type in manufacturing system, production layout and operation system.

The postal survey has been addressed to the managers; however only 42.9% from total received questionnaires are managers (see Table 1), the rest are included CEO/General Manager, 5.4%, Engineer/Executive, 48.2% and others, 3.6%. Although, the author believed that the respondent of the survey are management executive and able to represent their company and answer the question effectively. Almost a half of respondent are Multinational Company (MNC) which contributed 48.2%. Refer to Table 2, almost third quarter of respondents are Malaysian companies.

TABLE 1. RESPONDENT

Position	**Freq.**	**%**
CEO / General Manager	3	5.4
Manager / Assistant manager	24	42.9
Engineer / Executive	27	48.2
Other	2	3.6

N = 56

TABLE 2. COMPANY STATUS

Company Status	**Freq.**	**%**
Small Medium Industry (SMI)	21	37.5
Multinational Industry (MNC)	27	48.2
Government Link Company (GLC)	8	14.3
Company Ownership	**Freq.**	**%**
Malaysia	34	60.7
Foreign	22	39.3

N=56

Table 3 shows the companies' operational system. In terms of product characteristics, most of the companies are produced Make-to-Order (MTO) products, 75% compared to Make-to-Stock (MTS), 21.4%; and hybrids products, 3.6%.

For the types of industries, a quarter of respondents are Electric & Electronics industry followed by fabricate metal industry, 21.4%; plastic industry, 8.9%; and others (oil and gas; textile; wood; automotive. etc.), 44.7%.

The main business operation for most respondents are manufacturing which contributed 69.6%; followed by assembly, 16.1%; Original Equipment Manufacturer (OEM) and hybrids respectively 7.1%.

For process type, continuous type is the most for respondents, 33.9%; followed by repetitive, 15%; project base, 19.6%; Batch, 10.7%; and Job Shop, 8.9%.

The respondent are preferred to use process oriented layout, 34.5% followed by product oriented layout, 32.7%, fixed layout, 29.1% and hybrids, 3.6%.

In addition, the respondent are applied semi automation system in operation system which contributed 64.3% followed by manual operation, 25% fully automation, 7.1% and hybrids, 3.6%.

TABLE 3. COMPANY OPERATIONAL SYSTEM

Product Characteristics	**Freq.**	**%**
Make To Order (MTO)	42	75
Make To Stock (MTS)	12	21.4
Hybrids	2	3.6
Type Of Industry	**Freq.**	**%**
Electric & Electronic	14	25.0
Plastic	5	8.9
Fabricate Metal	12	21.4
Others	25	44.7
Main Business Operation	**Freq.**	**%**
Manufacturing	39	69.6
Assembly	9	16.1
OEM	4	7.1
Hybrids	4	7.1
Process Type	**Freq.**	**%**
Job Shop	5	8.9
Batch	6	10.7
Repetitive	15	26.8
Continuous	19	33.9
Project	11	19.6
Layout	**Freq.**	**%**
Fixed Position	16	29.1
Process Oriented	19	34.5
Product Oriented	18	32.7
Hybrids	2	3.6
Type of Operation System	**Freq.**	**%**
Fully Automation	4	7.1
Semi Automation	36	64.3
Manual Operation	14	25
Hybrids	2	3.6

N=56

Respondent were asked to declare the complexity level in their manufacturing operation. The manufacturing operation covered manufacturing system design, inventory management, supply chain management, human resources and job design, quality management system, and project management. Likert scale 1-to-7 was used. 1 represents the rating score of simple meanwhile 7 represent absolutely complex. The author realise that to determine the complexity level is very subjective but that is enough to show the complexity level through Likert scale 1-to-7. For the analysis purpose, the author only considered that the mean value which above than 4 are considered complex. The standard deviation (sd) is used to determine the relevant result of priorities when the mean value are equal. In this case, the small value of sd is preferred.

Table 4 shows the result of manufacturing complexity. According to the overall mean value, the respondents are agreed that the manufacturing complexity level is average of 4. However, it shown that there are several respondent declared for absolutely complexity in manufacturing operation. Quality Management System is considered the most complexity by overall respondent compared to others. In addition, the respondents were less agreed with work systems and factory transportation systems are complex. The rest of result can refer Table 4.

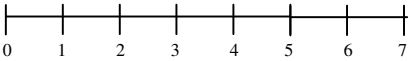
To identify the relationship between manufacturing complexities against companies' operational system, chi square test was performed. For significance level, p values which lower than 0.05 will be accepted. Table 5 shows the p value of chi square test. Base on Table 5, inventory management complexities which included inventory forecast, WIP product handling, and raw material handling are significance ($p<0.05$) and suggests not equal with business operation. In the other words, the complexity in manufacturing, assembly, OEM and hybrids operation are not equal. In addition, project scheduling is significance with the business operation to reject hypothesis null and accepted the hypothesis alternative. From Table 5, it shows that material handling management, organisation structure and project scheduling are significance with company operation system. It shows that the complexities in semi automation operation are not equal with manual operation, fully automation, hybrids operation and vice versa. The other types of complexity are equal among respondents.

TABLE 4: MANUFACTURING COMPLEXITY

	Rating Score								**mean**	**sd**
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**		
Manufacturing System Design										
Product & service design	6	2	3	6	11	13	6	9	4.68	1.6
Capacity planning	1	3	6	7	9	12	11	7	4.49	1.7
Material selection	3	5	2	6	14	6	16	4	4.47	1.7
Process selection	3	4	6	9	7	12	10	5	4.26	1.8
Material handling management	2	3	3	17	9	3	18	1	4.19	1.6
Facilities layout	3	5	4	12	13	7	8	4	4.00	1.7
Work systems	1	5	6	12	12	10	7	3	3.89	1.6
Factory transportation system	3	7	8	7	12	6	12	1	3.79	1.8
Inventory Management										
Inventory forecast	2	3	-	15	13	9	9	5	4.33	1.5
WIP product handling	2	4	2	12	12	11	9	4	4.24	1.6
Raw material handling	2	5	4	12	11	5	15	2	4.11	1.7
Finish product management	3	4	6	12	10	7	9	5	4.08	1.8
Supply Chain Management										
Logistics management	3	3	4	10	11	8	12	3	4.27	1.6
Vendor selection	2	3	4	9	14	10	11	2	4.23	1.5
Outsourcing	5	4	2	11	15	9	8	2	4.08	1.5
Make-or-buy decision	7	4	5	10	13	4	10	3	4.02	1.7
Human Resources & Job Design										
Organization structure	4	4	6	12	7	11	9	3	4.04	1.7
Job design	6	6	3	12	7	10	10	2	4.00	1.7
Quality Management System										
Quality control / Inspection	1	1	4	7	17	9	8	9	4.62	1.6
Quality assurance	1	1	2	8	20	7	11	6	4.58	1.4
Documentation	1	-	4	13	13	9	8	8	4.51	1.5
Approval system	2	1	4	13	12	4	13	7	4.50	1.6
Testing equipment	1	1	2	13	16	6	11	6	4.47	1.5
Standard operation procedure (SOP)	2	2	4	10	16	6	9	7	4.39	1.6
Project Management										
Project controlling	2	1	2	10	15	8	14	4	4.57	1.4
Project planning	2	1	3	10	14	9	13	4	4.52	1.5
Project scheduling	2	1	2	11	14	10	13	3	4.50	1.4

Note: N=56

Scale:
(Rating Score)



0 1 2 3 4 5 6 7

(Not Related) (Simple) (Complex) (Absolutely complex)

TABLE 5: CHI SQUARE TEST

	K1	K2	K3	K4	K5	K6
Manufacturing System Design						
Product & service design	0.112	0.078	0.517	0.420	0.523	0.476
Capacity planning	0.454	0.240	0.856	0.695	0.817	0.410
Material selection	0.848	0.425	0.209	0.873	0.689	0.494
Process selection	0.847	0.551	0.155	0.467	0.698	0.246
Material handling management	0.777	0.245	0.330	0.140	0.149	0.040
Facilities layout	0.259	0.370	0.954	0.114	0.431	0.330
Work systems	0.976	0.432	0.219	0.123	0.644	0.197
Factory transportation system	0.478	0.343	0.231	0.514	0.900	0.211
Inventory Management						
Inventory forecast	0.514	0.813	0.013	0.285	0.407	0.741
WIP product handling	0.253	0.397	0.039	0.588	0.609	0.152
Raw material handling	0.702	0.630	0.013	0.532	0.825	0.247
Finish product management	0.447	0.321	0.089	0.323	0.763	0.339
Supply Chain Management						
Logistics management	0.126	0.331	0.452	0.854	0.356	0.141
Vendor selection	0.877	0.629	0.072	0.996	0.756	0.706
Outsourcing	0.410	0.722	0.633	0.609	0.421	0.058
Make-or-buy decision	0.130	0.363	0.293	0.258	0.763	0.741
Human Resources & Job Design						
Organization structure	0.641	0.557	0.360	0.632	0.920	0.005
Job design	0.224	0.435	0.520	0.404	0.835	0.062
Quality Management System						
Quality control / Inspection	0.911	0.474	0.324	0.164	0.286	0.078
Quality assurance	0.856	0.456	0.363	0.442	0.282	0.686
Documentation	0.693	0.625	0.293	0.692	0.097	0.177
Approval system	0.497	0.672	0.692	0.705	0.168	0.114
Testing equipment	0.477	0.532	0.152	0.747	0.231	0.192
Standard Operation Procedure (SOP)	0.459	0.295	0.654	0.898	0.127	0.543
Project Management						
Project controlling	0.558	0.269	0.052	0.200	0.160	0.091
Project planning	0.511	0.197	0.075	0.320	0.221	0.058
Project scheduling	0.484	0.258	0.026	0.159	0.275	0.043

Note:
Significant Level: 0.05 (asymp. Sig (2 sided))
K1: Chi Square Test on product characteristics
K2: Chi Square Test on type of industry
K3: Chi Square Test on business operation
K4: Chi Square Test on process type
K5: Chi Square Test on layout
K6: Chi Square Test on operation system

IV. CONCLUSION

In the nutshell, complexity shows have negative correlation with major manufacturing activities in almost of the respondent companies. In addition, the complexities among the companies are almost equal. The complexities in inventory forecast, WIP product handling, and raw material handling in inventory management; material handling management in manufacturing system design; organisation structure in human resource and job design; and project scheduling in project management shows are not equal for business operation and companies' operation system. However, for the average result the level of complexity among respondents companies are intermediate. This is because; the average value for the result is just 4.0. These results perhaps will help others organisation to evaluate their manufacturing complexity. In the other hands, the companies can benchmark the existed manufacturing complexities in the current operation. For the future work, the author will define the manufacturing complexity by industry and more focus on the factor that influenced complexity. In addition, it will cover the total manufacturing complexity which not needed in daily operation.

ACKNOWLEDGMENT

Special thanks for Universiti Teknikal Malaysia Melaka (UTeM) for financial support (Short Term Grant No: PJP/2007/FKP/S308), all of respondents for the response and staff at Faculty of Manufacturing Engineering for your cooperation.

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