The impact of manufacturing complexity drivers on performance—a preliminary study

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Abstract. Manufacturing systems, in pursuit of cost, time and flexibility optimisation are becoming more and more complex, exhibiting a dynamic and nonlinear behaviour. Unpredictability is a distinct characteristic of such behaviour and effects production planning significantly. Therefore, this study was undertaken to investigate the priority level and current achievement of manufacturing performance in Malaysia’s manufacturing industry and the complexity drivers on manufacturing productivity performance. The results showed that Malaysia’s manufacturing industry prioritised product quality and they managed to achieve a good on time delivery performance. However, for other manufacturing performance, there was a difference where the current achievement of manufacturing performances in Malaysia’s manufacturing industry is slightly lower than the priority given to them. The strong correlation of significant value for priority status was observed between efficient production levelling (finished goods) and finish product management while the strong correlation of significant value for current achievement was minimised the number of workstation and factory transportation system. This indicates that complexity drivers have an impact towards manufacturing performance. Consequently, it is necessary to identify complexity drivers to achieve well manufacturing performance.

1. Introduction

Nowadays, many industries are looking for the best ways to improve productivity. However, there are many factors that influence the productivity reduction. One of the factors is complexity [1]. In the course of this progress, global manufacturing networks have become more and more complex inter alia due to the geographical distribution of sites, a growing product diversity, sophisticated manufacturing processes and many other aspects [2]. Complexity is still one of the biggest challenges in manufacturing due to increased variety, market volatility and distributed global manufacturing [3,4]. This is especially so for identification of the most relevant network segments from a complexity perspective is a critical success factor for a company’s competitiveness, since it provides information
to management about what kind of improvement measures might be most urgent and might deliver the most favourable impact in a certain economic situation [5].

In general, the drivers can be distinguished between internal and external factors and so-called complexity drivers [6]. To gain an understanding of the complexity, these external and internal drivers need to be identified first and their dependency on products and processes needs to be described subsequently [7]. Aelker et al., [8] stated that the most accepted differentiation is between the complexity arising from within a company (internal complexity), and the complexity caused by factors external to the organisation (external complexity). Yet, reviews the manufacturing complexity drivers, which provides the necessary knowledge to complete the first step of a complexity management initiative. Understanding and analysing the complexity drivers first will be an effective way to proceed to develop a clear strategy to deal with complexity [9].

Therefore, this initial study was conducted to explore the effect of complexity drivers in manufacturing productivity performance, based on two components namely Current Manufacturing Performance (CMP) and Manufacturing Complexity Driver (MCD) with the priority and the current achievement’s practice in Malaysia’s manufacturing industry. The findings can be used in shaping a more inclusive action to attain higher productivity performance. In addition, the results from this study can be used by the manufacturer, particularly to identify the main of MCD in order to achieve high CMP in production operations. Moreover, academicians can also use the evidence from this study to develop a new manufacturing framework to strengthen the current practice in manufacturing operations with the existing complexity drivers. The following sections would explain the research method underpinning the survey information, the results of statistical analysis from the survey, the measures of MCD and CMP, the relation between MCD and CMP and conclusions.

2. Research Method

The survey questionnaire is one data collection method to obtain quantitative data for statistical testing of the hypothesis from the literature reviews [10, 11]. The analysis was based on data obtained from the quantitative method by using statistical package SPSS. A questionnaire is conducted which that is comprised of 28 items on CMP and 15 items on MCD. For each item, the respondents were asked to rate each item with priority and achievement based on a five points Likert’s scale (e.g.: 1=unimportant to 5=critical for priority level and 1=very poor to 5=very good for current achievement). MCD is the dependent variable in the preliminary study to determine the significant driver through the mean score. CMP acts as the dependent variable to define the critical gap between the priority and the current achievement of each item in order to achieve better productivity. The internal consistency and reliability of the survey were tested using the Cronbach’s α reliability test [12]. Abolhassani et al., [13] stated that Spearman’s correlation evaluates a relationship between two variables, without making any assumptions about the frequency distribution of the variables and it was applied to measure the correlation of the relation of CMP and MCD. Out of 150 questionnaires sent, a total 61 were completed and returned. After a screening process, 54 of those completed with useful information went on for further analysis. With a response rate of 40.7 percent, it was believed that the answers would be reasonable and sampling technique is not used because of the survey not representing any population. The other intention is that this study is only an initial study in manufacturing complexity drivers on performance in Malaysia’s industry.

3. Result and Discussion

Descriptive statistics such as frequency, percentage and mean are the main statistical analysis employed. The survey questionnaire has been addressed to the appropriate person with at least two years’ experience in the company. The job title of the respondents is categorised into three types which are chief executive officer (CEO)/ director, manager/executive, engineer and others. Most of the respondents are in engineer position with 50.9%. Besides, the highest number of company ownership was from foreign countries (74.5%) typically from Asian company, followed by a local company (25.5%). 72.8% of the companies have more than 50% of the main business operation in
manufacturing operation. 72.5% of the companies have more than 50% of original equipment manufacturer (OEM) product.

Most of the respondents were from the electric/electrical products group (36.4%); followed by other products group and automotive products group (16.4%), other product group (14.5%), chemical/scientific products group (12.7%), 10.9% of the company has various product groups such as automotive, electric/electrical and mechanical and lastly, from mechanical engineering products group (9.1%). The majority of the respondents were foreign companies with more than 500 employees (74.5%), while the lowest respondent was from the local companies that 50 to 100 employees (5.5%). Meanwhile, 87.3% of the respondents have experienced in ISO 9001. Furthermore, the other management certification obtained by the company are TS 16949 (30.9%), ISO14001 (67.3%), OHSAS 18001 (52.7%) while 12.7 percent possess other management certification such as ISO 13485 and ISO 9002.

3.1 Analysis of Manufacturing Complexity Driver

In terms of MCD, the Cronbach’s alpha analysis shows that all are regularly reliable at a value of 0.874 for priority level and 0.871 for the current achievement. The dispersal of mean score for priority and current achievement of MCD are illustrated in Figure 1. The respondents agreed that all 15 items have fulfilled the priority where most of the manufacturers that prioritise the increase of customers’ demands (MCD13) have the highest mean score of 4.27. This is followed by the machine efficiency (MCD7), machine utilisation (MCD1), and capacity planning (MCD2) at a mean score of 4.18, 4.16 and 4.13 respectively. However, process selection (MCD4) is still less popular as this item ranked the lowest score with a mean score of 3.40. Increase of customer demands (MCD13) has the highest mean score too for MCD current achievement value at 3.85, followed by machine utilisation (MCD1) and finish product management (MCD12) at a mean score value of 3.82 and 3.80 respectively. Respondents also agreed that capacity planning (MCD2) and this reported a mean score value of 3.72. In contrast, process selection (MCD4) has less influence as the respondents appraised this with the lowest mean score value of 3.26. Based on Figure 1, increases of customer demands (MCD13) is the main MCD item that prioritised and achieved by most of the company because with customer demands the company have to grow their products unceasingly and adapt their production program and quantity [14].

![Figure 1. The performance of MCD in priority level and current achievement](image-url)
3.2 Measures of Current Manufacturing Performance

The Cronbach’s alpha analysis shows that all CMP items in the questionnaires were consistently reliable at a value of 0.907 for priority level and 0.931 for the current achievement of CMP. The respondents agreed that all 28 items have fulfilled the priority where most of the manufacturers that prioritised product quality (CMP27) have the highest mean score of 4.64 illustrated in Figure 2. This is followed by the on time delivery (CMP7), minimum cost (CMP26), and efficient space utilisation (CMP24) at a mean score of 4.54, 4.22 and 4.02 respectively. However, zero WIP (one piece flow) (CMP21) is still less popular as this item ranked the lowest score with a mean score of 3.12. As for CMP current achievement, on time delivery (CMP7) has the highest mean score value at 4.10, followed by product quality (CMP27) and minimum cost (CMP26) at a mean score value of 3.96 and 3.78 respectively. The adaptation of new technology (CMP1) had been recognised by the respondents which it is reported a mean score value of 3.68. In contrast, zero WIP (one piece flow) (CMP21) has less influence as the respondents appraised this with the lowest mean score value of 2.98.

![Figure 2. Comparison of mean score differences between priorities and the current achievement of manufacturing performance at manufacturing industry in Malaysia](image)

As shown in Figure 3, the largest gap formed between priority and current achievement is CMP 27 followed by CMP20 and CMP 26 which indicated that the current achievement of CMP is lower than the priority status. This result shows that most of Malaysia’s manufacturing industry has a high focus on product quality, on time delivery and minimum cost to achieve better manufacturing performance. This is not surprising because the focus on dealing with product quality and on time delivery issues is crucial to remain competitive in a modern manufacturing era in order to minimise cost. This is evidently shown in Figure 2 where these three components (product quality, on time delivery and minimum cost) have the higher mean score compared to the others component measured. Manufacturing industries are in pursuit of cost and time reduction without decreasing product quality [15, 16]. Improved product quality and on time delivery result in improved performance [17]. Antony et al., [18] implement Six Sigma to ensure there was an improvement in the on time delivery which was able to cost reduction. Most of the manufacturing industries aim the key performance measures are to increase yield, to maintain the quality of products, and to reduce the cost of operations [19].
Efthymiou et al., [15] stated that demand fluctuation along with the requirements of high product quality, low-cost, short lead time and high customisation may lead to an increase in manufacturing complexity in the globalised and interconnected market. This fact indicates that Malaysia’s manufacturing industries nowadays aspire to attain good manufacturing performance particularly to remain competitive in a new manufacturing environment and the complexity arises in the manufacturing. Figure 1 illustrated the lowest mean score for both priority status and current achievement component is zero WIP (one-piece flow). Zero WIP (one piece flow) is one of the lean tools where the parts are moved through operations from step to step ideally without any work-in-progress (WIP) [20]. It showed this component was not preferable by the manufacturing industry because of it is difficult to deploy [13].

### 3.3 The Relation Between Manufacturing Complexity Driver and Current Manufacturing Performance

In this study, Spearman’s correlation analysis between CMP with the MCD is created to form a total of 420 matrices of the relationship. The proposed hypothesis is addressed in this section which is:

- $H_{0A}$: All MCD is not significant correlation with CMP in priority level.
- $H_{1A}$: All MCD is a significant correlation with CMP in priority level.
- $H_{0B}$: All MCD is not significant correlation with CMP in current achievement.
- $H_{1B}$: All MCD is a significant correlation with CMP in current achievement.

Table 1 shows the test results between priority level and current achievement related to CMP and MCD. The Spearman $\rho$ correlation coefficient ranged from 0.021 to 0.716 for priority status and ranged from 0.031 to 0.699 for current achievement, at a significant level of 0.01, which indicated a moderate to the high-linear association between these variables. The analysis also shows that the item in the CMP has a significant relationship with MCD, where a strong correlation relationship existed between the efficient production levelling (finished goods) (CMP17) with finished product management (MCD12) at a value of 0.741 for priority status, the null hypothesis, $H_{0A}$ is rejected for these items. Production levelling is the lean concept for production smoothing [21] and [22] concluded that with production levelling able to manage product flow operation efficiently.

The correlation analysis between CMP and MCD for current achievement showed a significant value, 0.689 within minimising the number of the workstation (CMP25) and factory transportation system (MCD8). The null hypothesis, $H_{0B}$ is rejected for these items since the items are significant correlate with MCD and CMP. Pourvaziri and Pierreval [23] identified that the location of machines is one of the key issues regarding manufacturing systems’ performance. Indeed, if the material flow between two machines becomes too high, then it may be necessary to add new transporters to the system, which adds new costs, machines or workstations with high flow rates are allocated close to each other to minimize the total distance of the material flow.
Table 1. Spearman correlation between MCD against Current Manufacturing Performance

| Item   | Current Manufacturing Performance Priority | Current Achievement |
|--------|--------------------------------------------|----------------------|
| MCD2   | CMP20                                      | CMP7, CMP11          |
| MCD5   | -                                          | CMP23                |
| MCD6   | CMP24                                      | CMP12, CMP25         |
| MCD7   | CMP28                                      | CMP18, CMP22         |
| MCD8   | -                                          | CMP24, CMP25         |
| MCD9   | CMP17                                      | -                    |
| MCD10  | CMP19                                      | CMP7, CMP18          |
| MCD11  | CMP14                                      | -                    |
| MCD12  | CMP14, CMP17                               | -                    |

4. Conclusion

As a conclusion, this initial study has shown that the MCD has a strong influence on the manufacturing performance. Coupled with correlation analysis, this showed that each of the practices in MCD has a significant positive correlation with each item in the manufacturing sustainability components. The study is still relatively exploratory. Future studies could investigate the management of complexity with the existing complexity drivers at Malaysia’s manufacturing industry. The findings in this study can be used as a basis for the next stage of a study in developing a more widespread approach to manufacturing complexity management, primarily in Malaysia’s manufacturing industry.

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Appendices

1. Information on Current Manufacturing Performance (CMP)

What are your current manufacturing performances in your company from the past two (2) years? (On a five point Likert-scale)

| Item | Manufacturing Performance |
|------|---------------------------|
| CMP1 | Adaptation of new technology |
| CMP2 | Decrease customer lead time |
| CMP3 | Decrease throughput time |
| CMP4 | Enhanced product variety |
| CMP5 | High capacity of innovation |
| CMP6 | Minimise setup time |
| CMP7 | On time delivery |
| CMP8 | Speed up changeover time |
| CMP9 | Effective machine optimisation |
| CMP10 | Increasing Kaizen activities |
| CMP11 | Minimise machine configuration |
| CMP12 | Operator flexibility and innovativeness |
| CMP13 | Optimize Poka-Yoke |
| CMP14 | Proactive Total Preventive Maintenance (TPM) Practice |
| CMP15 | Process line balancing |
| CMP16 | Effective pace of production (Takt time) |
| CMP17 | Efficient production levelling (finished goods) |
| CMP18 | Organised Just-in-Time (JIT) for raw material |
| CMP19 | Organised Kaban system for Work-in-Progress (WIP) |
| CMP20 | Zero missing/misplace material |
| CMP21 | Zero WIP (one piece flow) |
| CMP22 | Effective layout configuration |
| CMP23 | Effective material flow |
| CMP24 | Efficient space utilisation |
| CMP25 | Minimise number of workstation |
| CMP26 | Minimum cost |
| CMP27 | Product quality |
| CMP28 | Simplified operation procedure |

2. Information on Manufacturing Complexity (MC)

What are your complexity drivers in your company from the past two (2) years? (On a five point Likert-scale from unimportant to critical for priority and very poor to very good for current achievement)

| Item | Manufacturing Complexity Drivers |
|------|----------------------------------|
| MCD1 | Machine utilisation |
| MCD2 | Capacity planning |
| MCD3 | High product mix |
| MCD4 | Process Selection |
| MCD5 | Material handling management |
| MCD6 | Space utilisation |
| MCD7 | Machine efficiency |
| MCD8 | Factory transportation system |
| MCD9 | Inventory forecast |
| MCD10 | WIP product handling |
| MCD11 | Raw material handling |
| MCD12 | Finish product management |
| MCD13 | Increases of customer demands |
| MCD14 | Increases of customer numbers |
| MCD15 | Specifications of products |