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FORMULATING THE STRATEGY IN MANAGING MANUFACTURING COMPLEXITY: A PRE-REVIEW

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ABSTRACT: *The purpose of the paper is to present a conceptual framework to formulate the strategy in managing manufacturing complexities. For model development, several numbers of journals were reviewed and semi-structured interview with four operation managers in manufacturing sector were performed. As a result, the framework is divided into two main categories: production strategy and human management. The sub categories for production strategy are manufacturing area, scheduling management and supply chain management; while for human management are self-assessment and organizations' transformation. There are a lot more elements under these sub categories. Each sub category is able to highlight a significouldce relationship with each other where manufacturing activities involved all of them. The conceptual framework initiated in this paper is able to provide a general guidance for manufacturer to manage any sort of manufacturing complexity appeared during their manufacturing activities works or personnel to take action after determining the manufacturing complexity areas and components around their routine activities.*

KEYWORDS: Manufacturing Complexity, Framework, Production Strategy, Human Management

1.0 INTRODUCTION

Manufacturing industry is improving rapidly time after time. The improvement in manufacturing industry is parallel with rapid improvement in technology. Today's technology is expanding positively which is well-intentioned from the technology provider's perspective, but from the manufacturers' perspective, the expanding technology allows thousands of extra works and determination to compete in the industry. The nature of competition in manufacturing industry also becoming tighter reacting with situation discussed in the beginning of this paper. This scenario showed that the challenges in manufacturing industry are getting bigger and stronger which lead manufacturer to study in order to stay competence in manufacturing industry.

At present, manufacturing complexity is becoming multifaceted and has converted a new great challenge for industry. Wu et al. [1] defined manufacturing system complexity as a comprising system complexity, operator task complexity, operator behaviour complexity, supervisory task complexity, training effectiveness, and man–machine interface effectiveness. It is stated clearly and could be conclude that manufacturing complexity occurred in every area of manufacturing activities. It is also spreading across the organization silently without noticed and could be defined as the malfunction of an element. The mapping of interdependence between those elements, and measuring the metrics of the elements and their interrelationships, if elements are missing or defective, not properly interfacing or misaligned, or not performing correctly, then it is considered manufacturing complexity occurred [2].

Even though many publications exist on manufacturing complexity, unfortunately, very little research has investigated the ways in managing complexity in production activities and human management. So, the objective of this paper is to highlight the potential relationship of both production activities and human management in managing manufacturing complexity. Besides that, this paper also showed the potential relationship between the criteria presented which is based on literatures and semi-structured interview with four experienced operation managers in manufacturing sector. The followings section would explain the research method, conceptual framework in formulating the strategy in managing manufacturing complexity and some useful conclusions and suggestions for future research.

2.0 RESEARCH METHOD

This research paper is divided into two phases. Firstly, the research begins with a literature review. The literature review was conducted by reviewing several previous research papers that related with manufacturing complexity. The research papers involved with every area in manufacturing industry and not limited to certain area only. The investigation is focussed on the manufacturing complexity issues and narrowed down to the possible ways and strategies that may be useful in managing manufacturing complexity. In the second phase, the conceptual model examined in this paper was developed through an examination of literature on the aspects of the production activities and human management and expert review from four different operation managers. The "aspects" are summarised using five sub categories based on the dominant area where each strategy is classified into them. This is important to make a clear view on which area the discussion is being made. These sub categories then are categorized under two main elements in manufacturing background. These two main categories help to divide the strategies under two different areas that help in simplifying the strategies in managing manufacturing complexity.

3.0 MANAGING MANUFACTURING COMPLEXITY

Managing manufacturing complexity is important in order to make the manufacturing routine running smoothly while eliminating any uncertain activities. As manufacturing complexity included internal and external factors [3][4], the managing factors need to cover both areas. Even though external factor seems difficult to be reached and controlled, organizations have to do the best to minimize factors affected by external factors. As stated by Sivadasan & Efstathiou [5], manufacturing complexity covers a broad scope from computational complexity to operational and biological complexity and even to social complexity. This clearly shows that in managing manufacturing complexity, all aspects in manufacturing activities are needed to be included. Each activity left behind may give a big impact on the manufacturing performance in either short term or long term.

From the research made, the possible and suitable elements are included in the framework and categorized under two main elements namely production strategy and human management. Next chapter would be discussed in detail about the framework in managing manufacturing complexity.

3.1 The Conceptual Framework

The conceptual framework is shown in Figure 1. The development of the framework is based on two main division which are production strategy and human management thus proven to be parallel with Sivadasan & Efstathiou [5] which categorized manufacturing complexity in two categories namely structural and operational. Structural suit with human management while operational with production strategy. In Figure 1, there are fifteen strategies in managing manufacturing complexity which then narrowed down into five categories. The list of the strategies under each categories are as follow: (a) Manufacturing Area; develop capacity of operational level, reengineering, simulation based approach and mixed model assembly system. (b) Scheduling Management; implement blocking constraint and shortest batch rule. (c) Supply Chain Management; modular supply chain and well managed supply chain. (d) Self-Assessment; measure cost of complexity, measure the complexity level and focus on relevant aspects. (e) Organizations' Transformation; unify all department, join other competencies, great human and machine interaction and good technical design idea.

The balance number of strategy on both side of the framework shows the significance of both production strategy and human management in managing manufacturing complexity. Next chapter would discuss in details on both main categories.

3.2 Production Strategy

Production strategy is divided into three sub categories which are manufacturing area, scheduling management and supply chain management. All these components are considered under production strategy due to its direct relation with production activities. Production strategy involves any activity during the production or adding value process. It is also involves the activities in determining the process that bring direct impact to the production process. For example, by implementing simulation based approach in manufacturing, the way products are producing would be different in which it would follow the route that simulation told as the best. So, the quality and quantity of the products may differ from the previous route.

The first subcategory is manufacturing area. Under manufacturing area there are developed capacity of operational level, reengineering, simulation based approach and mixed model assembly system. In production, it is important to know the optimum level of organization's capability. There are two types of product in the market which are a new product and modification of existing product. Each product has different load to the production and by differentiating them would help to determine the capability that suit with the product strategy [6]. By developing the capacity of operational level, a lot of complexity or problems may be avoided. Doolen et al., [6] discussed that in production, overachieving and underachieving are bringing complex environment to the organizations. Both are considered bad thus determining the optimum capacity operational level is important to manage this complexity. Next strategy is reengineering. Reengineering is one of the ways to simplify processes in manufacturing. Thus, there would be less complex as stated by Arteta and Giachetti [7] that easier and more agile process come from less complex process that could be achieve using reengineering. This statement showed that less complex process is easier to change and more agile. So, reengineered process would be easier to change and less complex. Besides reengineering, simulation is a well-known in manufacturing. With simulation, the production could be predicted and it is reliable up to certain limit. Research conducted by Papakostas et al., [8] indicated that, in order to overcome the shortcomings of analytical methods in investigating complexity of manufacturing systems, a series of simulation-based approaches are proposed which are based on uncertainty analysis and sensitivity analysis. Simulation is a useful tool to approximate the complexity and performance of a certain process thus suggested numbers of ways to solve manufacturing problems especially manufacturing complexity. Nowadays, there are several simulation software available in market and some advanced software may include intrinsic system behaviour and other uncertainty that may occur depending on manufacturing operations related. As example in manufacturing complexity problem, experts have developed system that may come out with manufacturing complexity index and the proposed solutions towards them. This considered as a good system in every aspects in manufacturing operations. As product variety becoming essential on consumers' view, mixed-model assembly systems has been recognized as major enablers to handle the increased variety [9]. Logically, mixed model assembly

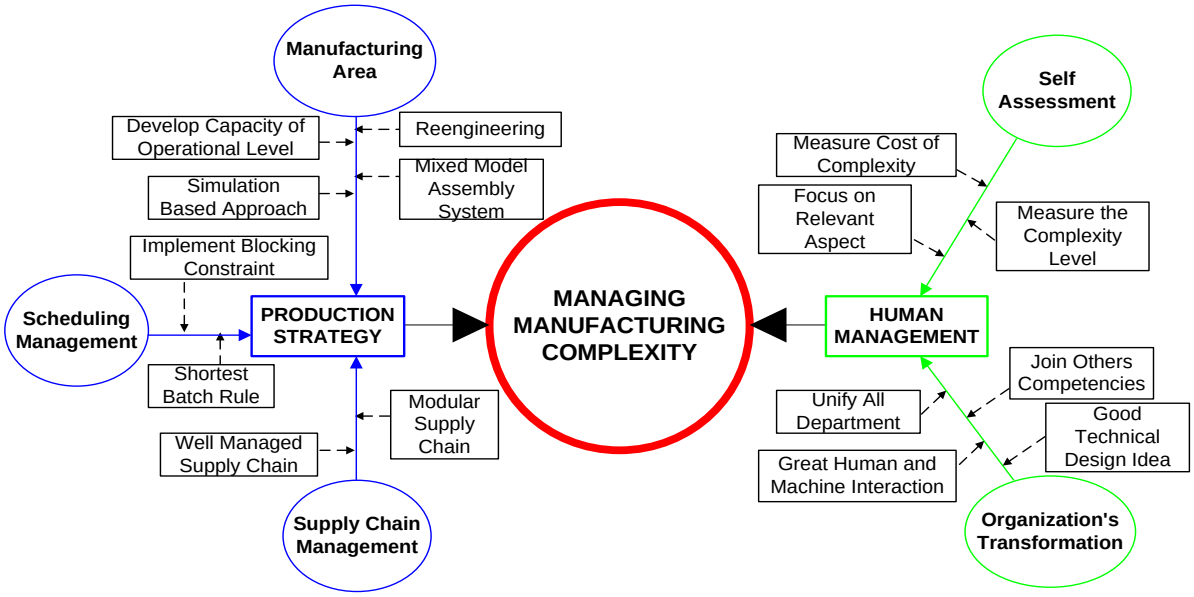

Figure 1: The Strategy Framework in Managing Manufacturing Complexity

system would allow the production runs various model simultaneously. Even though this strategy may effects on big initial cost spending, it would beneficial in long term production run. Surely, marketing and sale department would play their role towards that. Various industries are practicing mixed-model assembly systems since they bring various benefits.

Next subcategory is scheduling management. Scheduling in manufacturing industry is very important since it covers every area involved in manufacturing. There are many strategies in scheduling. One of the strategies that suitable in handling manufacturing complexity is implement blocking constraint. This may induce a situation where a job, which has completed its processing on a machine, blocks this machine until a downstream machine becomes available [10]. Even by implementing blocking constraint may result in process delay, it is very useful to reduce and manage complexity. The other strategy is shortest batch rule. The structure in shortest batch rule is simple where it concern with batch completion time instead of job completion time [11]. As the shortest batch rule is simple, there are many real problems applied it for example crane scheduling at port, automotive repair shop scheduling and scheduling customer order. Both strategies in scheduling management make the scheduling simple thus eliminate any possible factor that complexity may occur. There may be other strategy that suit with this scheduling management category but author find that both strategy included in this paper are the most effective based on previous researches.

The last is supply chain management. Supply chain need to be well manage because it is the beginning of every process in manufacturing. Mismanage supply chain may result in quality, quantity and performance drop thus ruin the organization's reputation. Modular supply chain is a strategy that suit to manage complexity. Modular supply chain is recognized as enablers in handling product variety that lead to manufacturing complexity [9]. Modular supply chain spreads the tasks of assembly to entire station and not leaving the workload to final assembler only. Only few assembly modules would be carried out in the final station thus decreasing complexity. Modular supply chain also would give risk and responsibility equally towards the subassembly station along the production line from the beginning till the end. Various industries have implemented modular supply chain strategy especially automotive and aerospace industry and proven to be effective particularly from manufacturing complexity view.

The production strategies that been discuss in this chapter would help and guide manufacturers in order to manage manufacturing complexity. This may give a positive impact in their manufacturing performance thus improving their reputation and revenue. Next chapter would discuss in detail on the other category which is human management.

3.3 Human Management

Human management is the other factor that leads to manufacturing complexity. Human is an identity that moves and operates things in an organization. Human also think and decide the dos and don'ts. Thus human is considering as an important factor in manufacturing complexity. There are only two sub categories in human management but both categories are very significance. The categories are self-assessment and organization's transformation.

Self-assessment has three sub elements which are measure cost and level of complexity and focus on relevant aspects. In measuring cost of complexity, the decision is to find the complexity driver that invested more cost but does not contribute much to customers' buying decision [4]. This action would reduce the unnecessary cost bear by the

manufacturer. For example, in manufacturing operation, a small investment in packaging may resulted a big difference in customer buying decision. Besides measuring the cost of complexity, measuring the complexity level is also suggested in order to manage manufacturing complexity. By measuring the complexity level, organizations could identify and quantify high manufacturing or operational complexity by areas and tasks [4]. This measure could be used by the organizations to identify the areas that required extra handling or tighter control. The complexity level measurement also could determine the sources of complexity thus give more opportunity to the organization to eliminate them. This act in the other word is focus on relevant aspects. Previous researchers have come out with various ways to measure the complexity level in certain manufacturing areas and operations. In dealing with complexity, among the favourite solution is to simplify things to reduce the complexity. Micheal *et al*., [12] stated that in managing manufacturing complexity, a successful model simplification or reduction is necessary. The simplification or reduction model would lead to the key aspects in manufacturing complexity. For example, in a semiconductor industry, the effect of different reactor configurations and operating conditions on etching uniformity could be captured by focusing on a couple of characteristic patterns of wafer wide etching that could be experimentally determined. The effect of antimicrobial agents on heterogeneous microbial populations could be captured by focusing on a few crucial parameters [12]. It is completed and clearly discussed that self-assessment is crucial in managing manufacturing complexity because correcting themselves is needed before correcting others.

The other sub category under human management is organizations' transformation. The word transformation shows that it is involved in something important and big to the organization. The term transformation here means something bad in the organization's culture that should be eliminate or modify in order to bring the bright future to the organization as reality. There are four sub elements in human management which are unify all department, join other competencies, great human and machine interaction and good technical design idea. Firstly, the gaps between departments should be eliminated. There are a lot of conflicts and misunderstanding between departments that lead to the manufacturing activities experience greater complexity. Finance, human resources, marketing, production, design and other departments under one roof of an organization should find relevant solution to solve this conflict to manage manufacturing complexity well [4]. Operation and marketing department should seat together and speaking the same language, review the same knowledge base, sharing incentives and make decision. On this particular problem, Chief Executive Operation (CEO) or someone with a higher hierarchal level plays important role to ensure that every personnel are working towards the same vision and mission of the company. On the other hand, Schuh *et al.,* [13] proposed that by joining and sharing others competencies and capacities could increase overall equipment efficiencies (OEE) thus improve the quality. This step would improve the capability of an organization to actively react to the changing customer needs. Sharing competencies and ability by collaborating with other company would greatly reduce space, human resource and decrease the rate of underutilization [13]. The intellectual capital of each company also would be actively developed and thus creating the environment where every company has the special ability or experts in different areas. The third strategy is to provide great human and machine interaction. Human and machine plays an important role in determining manufacturing performance. It is very important to have a great human and machine interaction. Even with complicated and high machines sensitivity, the great interaction among these two entity may solve the gap between them; human and machine. The last transformation that could help in managing manufacturing complexity is having a good technical design idea. This is where the new generation should take into consideration due to their creative and fresh idea that follows the current trend in manufacturing industry. Design idea guides good design decisions to create the least difficult technical systems with only minimal essential inborn complication without any extra acquired complexity [14]. Poor technical design would impacted on increasing manufacturing complexity from the beginning until the end of manufacturing cycles. These strategies show that organizations should think to allow some transformation that take place internally. Upon the transformation taking place, organizations may stay competence in the manufacturing industry and meet current customer needs.

4.0 CONCLUSION

As a conclusion, the proposed formulating strategy in handling the manufacturing complexity includes two main categories which are production strategy and human management. These categories are then expanded to another five sub category which three categories is under production strategy while the other two lied under human management namely manufacturing area, scheduling management, supply chain management, self-assessment and organizations' transformation. The strategies included in the framework may help in handling or managing the manufacturing complexity that occurred around the organizations. In order to validate the framework, future study might take place where field study is required in Malaysia's manufacturing environment. The field study may verify the proposed framework thus make any improvement if necessary.

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