Managing manufacturing complexity and sustainability: A fuzzy AHP approach

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ABSTRACT: The complexity of current manufacturing industry landscape has create an urgency for the industry players to be more responsive and sustainable in their manufacturing routines. Manufacturing firms have to adapt changes in practices to stay relevant in the market. Aiming to provide a clear practical guide for manufacturing firms, this research adopting elements and practices listed as significant in Malaysian industry. These elements and practices have been analyzed using fuzzy analytic hierarchical process. The findings have been used as the main input towards the framework development. The results lead towards the arrangement of the elements and practices according to the priority level. The integration of sustainability practices and complexity elements have built up a comprehensive framework. The results shows that sustainability practices are being prioritized by economic sustainability respectively while the most important complexity classification is internal complexity with its classification of productivity complexity. The framework developed will provides guide for manufacturing firm in practical decision making and for researchers to make deeper research within the similar scope.

Keywords: *Manufacturing complexity; Manufacturing sustainability*

1. INTRODUCTION

Manufacturing industry has experienced it's forth revolution which emphasized on internet of things and digitalization [1]. Malaysian manufacturing landscape also has impressed by this revolution where a massive efforts happened which could be observed from firms' strategic orientation changes. The scenario created complex manufacturing circumstances which led towards incorrect and uncertain decision making [2]. Table 1 shows the manufacturing complexity (MC) classifications and their respective elements [3]. MC is divided into internal and external complexity. Internally it has been classified into organizational, operational and productivity complexity. Meanwhile, there are product, market and supply chain complexity externally.

Aside from the elements, this research also looked into the interaction between MC elements and manufacturing sustainability (MS) practices. Referring to Kasava et al., [4], the intense to conform to the sustainability requirement is inevitable. Environmental and social sustainability practices have been highlighted by stakeholders while economically is essential for the firms' continuity within the industry [5].

Table 1 Manufacturing complexity elements

	Factor	Item
Internal Complexity	Organizational Complexity	Sufficient and effective employee training
		Improve organization's culture
		Managing employees behavior
		Fulfilling key performance index (KPI)
		Information flow management
		Establish standard operation procedure (SOP)
	Operational Complexity	Manage production records system
		Needs to use simulation
		Inventory management
		Material handling system
	Productivity Complexity	Reduce production cost
		Reduce production time
		Quality inspection requirements
External Complexity	Product Complexity	Expectation of secondary stakeholder
		Acceptance of variability in product quality
		Needs to control environmental pollution
		Variety of machines required
		Implementation of flexible manufacturing system
		Needs to use user friendly machine/equipment
		Standards and regulation by authority
	Market Complexity	Market trend changes
		Customer trend changes
		Action of competitor
		Variety of product
	Supply Chain Complexity	Size of supplier
		Demand variability in volume
		Various manufacturing uncertainty

2. METHODOLOGY

This research consisted of two phases in data collection. Firstly, a set of questionnaire survey is constructed from literature review. It is submitted to 50 representative of manufacturing firms across Malaysia following the sample size for exploratory research [6]. Then, the collected data is analyzed by correlation analysis and data reduction factor analysis using SPSS. This resulted on the classification division and elimination of insignificant elements and practices. Lastly, the final list has been used in interview session of pair-wise comparison for fuzzy analytic hierarchical process (FAHP). FAHP could eliminated data vagueness, disagreement on the result and easily understood by all personnel level in an organization. This method provide weightage for each elements and practices for priority level arrangement.

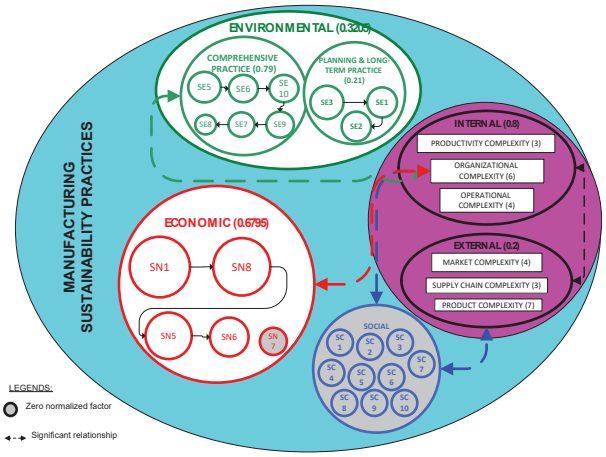
3. RESULT AND DISCUSSION

The consistency ratio for all matrices have been calculated and determined to be consistent by consistency ratio less than 0.1. Result and findings are presented in Table 2 for both MC and MS.

Table 2 FAHP weightage results

Criteria	Class.	Sub-Classification
MC	Internal Complexity 0.8	Productivity Complexity 0.5302 Organizational Complexity 0.2646 Operational Complexity 0.2052
	External Complexity 0.2	Market Complexity 0.6311 Supply Chain Complexity 0.2114 Product Complexity 0.1575
MS	Economical Sustainability 0.6795	
	Environmental Sustainability 0.3205	Comprehensive Practice 0.7917 Planning & Long-Term Practice 0.2083
	Social Sustainability 0	

Based on the results obtained, internal complexity has being far more importance than external with weightage of 0.8 compared to 0.2. Among three sub classification of internal MC, the top priority goes to productivity complexity consisted of quality inspection, production time and cost. Next, economical sustainability has placed on the top priority among others MS practices. Minimizing the overall production costs has been highlighted as to main practice in economical sustainability practices. Considering the relationship occurred among the variables, the final framework is developed as shown in Figure 1.



SE1 Increase recycle material	SC1 Improve employee satisfaction
SE2 Increase non-toxic material	SC2 Improve employee education and skills
SE3 Consider recycle material in design	SC3 Improve work environment organization
SE5 Environment management	SC4 Compliance environmental safety and regulation
SE6 Materials and energy consumption reduced	SC5 Consider operation impact on community
SE7 Pollution prevention	SC6 Improve customer satisfaction
SE8 Reduce emission	SC7 Collaborate with communities on environmental issues
SE9 Reduce waste	SC8 Posses environmental policy statement
SE10 Consider environmental effect from operation	SC9 Reduce local community complaint
SN1 Minimize overall production cost	SC10 Improve supplier relation and commitment
SN8 Purchase materials and components based on demand	
SN5 Reduce total production time	
SN6 Minimize transportation cost	
SN7 Consider risks in investment	

Figure 1 Sustainable manufacturing complexity management framework

Framework in Figure 1 shows the interaction between all the elements and practices involved in this research. The framework also has arranged them in sequence according to the priority level. The dotted arrows in the framework show that organizational complexity has significant correlation with all the MS practices.

However, social sustainability has been placed at the bottom priority due to the weightage value of 0. Social sustainability practices have been placed as unimportant by Malaysian manufacturing firms. Eventually, this perception is gradually changing with efforts done by many associations.

4. CONCLUSION

This research has proposed a guidance for manufacturing firms in selection of areas to be highlighted towards the manufacturing complexity management especially in Malaysia. It is suggested that the internal complexity to be given the priority to be managed while, the economic sustainability should always be the priority in every decision making. The framework also is useful for researchers to dig deeper on the similar research areas.

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