Structural Decisions of Sustainable Manufacturing Strategy with Fuzzy Analytic Network Process (FANP)

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ABSTRACT

This paper proposes the use of fuzzy analytic network process (FANP) in identifying the content of the structural decisions of manufacturing strategy that integrates sustainability and the classical manufacturing strategy framework, considering firm size as a relevant component in decision-making. Fuzzy set theory elucidates judgment through linguistic variables while analytic network process (ANP) handles the complexity of the decision-making brought about by subjectivity and relationships among components in the decision problem. A group of experts in manufacturing was tasked to elicit judgment in pairwise comparisons following in the methodology of the ANP. Results also show that structural decisions that support sustainability integrate backward supply chain. This supports existing approaches particularly on sustainable supply chain and green purchasing. The contribution of this work lies in adopting a multi-criteria decision-making (MCDM) framework that identifies the content of the structural decisions of a sustainable manufacturing strategy.

Keywords: *Analytic Network Process, Firm Size, Fuzzy Set Theory, Manufacturing Strategy, Sustainability*

1. INTRODUCTION

The work of Wickham Skinner in 1969 became the foundation on highlighting the role of manufacturing strategy in achieving corporate goals and objectives. Skinner (1969) promotes a hierarchical top-down strategy framework that links corporate, business and functional strategies wherein manufacturing strategy is part of (Hayes & Wheelwright, 1984). This framework was plausible and highly regarded by domain scholars (Voss, 1995; Hallgren & Olhager, 2006; Gonzalez et al., 2012). Various works agree that a manufacturing strategy could

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only support business strategy if a sequence of decisions over structural and infrastructural categories is consistent over a sufficient amount of time (Wheelwright, 1978). Structural decisions which include process technology, facilities, capacity and vertical integration, forge long-term impacts on the organization and require huge amount of investments at one point in time. On the other hand, infrastructural decisions which include organization, manufacturing planning and control, quality, new product introduction and human resources, are inherently strategic and require less investment of resources but are highly costly when changes are introduced after they have been placed. The concepts behind manufacturing strategy have been tested over decades of diligent research and application. However, the field is criticized over its lack of progress in theory building, empirical studies and integration with current approaches (Gonzalez et al., 2012) particularly with the current demands of sustainability.

Pressing concerns on sustainability have compelled manufacturing firms to incorporate in their decision-making processes the agenda of the triple-bottom line which consist of economic, environmental and social issues (Elkington, 1997) especially those related to material, energy and wastes (Despeisse et al., 2012; Smith & Ball, 2012) as the primary concerns of manufacturing. At least one-third of global energy consumption and carbon emissions is attributed to the manufacturing industry and projections show that this figure is likely to double over the next five decades. To address these concerns, a specialized field of sustainable manufacturing is conceived which is then defined by the U.S. Department of Commerce as "the creation of manufactured products that use processes that minimize negative environmental impacts, conserve energy and natural resources, are safe for employees, communities and consumers and are economically sound" (Department of Commerce, 2008; Joung et al., 2012).

Many researchers maintain that the choice of manufacturing firms on manufacturing strategies depends on its firm size. Ageron et al (2012) and Law and Gunasekaran (2012) argue that differences on the responses of firms are attributed to the fact that sustainability approaches require relatively high amount of investment and for smaller firms such as SMEs, resources in terms of time, manpower and finances become an issue (Tsai & Chou, 2009). Schrettle et al. (2014) claim that firm size becomes a moderator of the differences in the level of sustainability efforts a firm undertakes. Hansen and Klewitz (2012) and Bos-Brouwers (2010) also state that when both large and small firms can engage in sustainability-oriented innovation, small and medium sized enterprises (SMEs) will innovate differently compared to large firms. Although significant effort has been devoted to the theoretical and empirical implications on the differences between large firms and SMEs in the context of innovation (Symeonidis, 1996; Laforet, 2013), eco-innovation (Bos-Brouwers, 2010; Triguero et al, 2013; Klewitz & Hansen, 2014) and sustainability (Tsai & Chou, 2009; Bourlakis et al., 2014; Henriques & Catarino, 2015), limited work has been done on identifying the content of the manufacturing strategy when sustainability and firm size are brought into context.

Hallgren and Olhager (2006) provide a quantitative approach in developing a manufacturing strategy taking into account the decision categories, manufacturing objectives, and market requirements with recursive guide in improving these components in closing the gap between market requirements and manufacturing objectives. The conceptual frameworks of Azapagic (2003), Reich-Weiser et al. (2008) and Subic et al. (2012) on sustainable manufacturing are detached from mainstream manufacturing strategy and tackle issues of sustainability with reference only to the triple-bottom line. Arguably, the compatibility of the approach to sustainability with the strategic manufacturing decisions of firms becomes unquestionable.

A significant attempt of integration was proposed by Johansson and Winroth (2010) which attempt to explore the impact of stakeholders' concerns for the environment on manufacturing strategy formulation process. This research direction has been inspiring due to

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