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A PROPOSED SUSTAINABLE MANUFACTURING STRATEGY FRAMEWORK

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Abstract: Current approaches and initiatives that attempt to address sustainability in manufacturing lack a clear direction on providing informed decisions on key manufacturing decision areas. The challenge lies in embedding sustainability to the usual competitive orientation of manufacturing firms. Thus, this paper proposes a framework in formulating a sustainable manufacturing strategy which is grounded on sustainability without disregarding the internal and external competitive functions of manufacturing. The proposed framework attempts to integrate classical theories on manufacturing strategy and the current demands on sustainable manufacturing in an attempt to formulate a sustainable manufacturing strategy that describes two distinct functions of manufacturing – competitiveness and sustainability. The relevance of the framework lies in its capacity to be quantitatively explored using different tools, such as multi-criteria decision-making methods. Issues and relationships of different components of the framework are presented in this paper. The contribution of this work is on the integration of sustainability and manufacturing strategy into a holistic framework that highlights both the sustainability and the competitive functions of manufacturing.

Keywords: manufacturing strategy, sustainable manufacturing, framework.
JEL Classification: M11, M14.

Introduction

The work of Wickham Skinner in 1969 which was published in Harvard Business Review served as a ground-breaking work of what is popularly known today as the manufacturing strategy (Skinner, 1969). Hayes and Wheelwright (1984), building upon Skinner, defined manufacturing strategy as a consistent pattern of decision-making in the manufacturing function that linked to business strategy. Following, this has raised the hierarchical

top-down strategy framework of Skinner which links corporate strategy to business strategy and links business strategy to manufacturing strategy. As a hierarchical structure, the framework permits consistency of corporate strategy and manufacturing strategy. This classical framework was impressive and widely accepted as it eventually became the guidelines of later frameworks emerging in this field (Hayes and Wheelwright, 1984; Wheelwright, 1984; Kotha and Orne, 1989; Hallgren and Olhager, 2006). Domain scholars agree that manufacturing strategy does not only support business strategy, i.e., its internal function, but it also translates manufacturing firms' strengths and resources into opportunities in the market, i.e., its external function (Wheelwright, 1984). This draws manufacturing strategy into various discussions between scholars and practitioners of this field.

It was further agreed that a manufacturing strategy could only support business strategy if a sequence of decisions over structural and infrastructural categories is consistent over a considerable amount of time (Wheelwright, 1978). Structural decisions, such as process technology, facilities, capacity and vertical integration, forge long-term impacts to the organization and require a huge amount of investments. Infrastructural decisions, on the other hand, such as organization, manufacturing planning and control, quality, new product introduction and human resources, are strategic and require less investment at one point in time, but changes are too costly when certain decisions are already in place. When decisions are consistent over these decision categories, manufacturing strategy develops a set of manufacturing capabilities which are aligned to the competitive priority carried out by the business strategy. The set of competitive priorities assumed by the business unit is a convergence of both corporate strategy and business position – market or technology-leader – intended to gain advantage over its competitors. This entire concept of manufacturing strategy has been established and empirically tested over decades of research and practical applications. However, recent observation criticizes this field over its lack of progress in theory-building, empirical studies and integration with recent approaches (Gonzalez, et al., 2012), especially with the current demands for sustainability.

Emerging concerns towards environmental degradation, resource consumption and social equity in the past four decades or so, the concept of sustainable development became central to development discourses and policy formulation. The pattern of technological development, for instance, has been recently linked to the sustainable development agenda such that appropriate and clean technologies that conform to environmental and social demands must be highly prioritized (Ocampo, 2015). One significant pivot to sustainability is the manufacturing sector (Joung, et al., 2013) due to its high volume of resource consumption, increasing annual introduction of new products that relatively require a high amount and generation of materials, energy and wastes, increasing volume of emissions throughout product life cycles and the collective effect of manufactured products and manufacturing processes to immediate stakeholders (Ocampo and Clark, 2014a). Sustainable manufacturing enables the development of products and processes that address environmental stewardship, economic growth and social well-being, simultaneously. Thus, manufacturing firms at present are confronted with relevant issues of developing manufacturing strategy on one hand and addressing sustainable manufacturing on the other hand. Recent frameworks seem to disintegrate these two issues and limited information is available on approaches that link them together. The framework developed by Hallgren and Olhager (2006) provides a quantitative approach in developing a manufacturing strategy from the perspectives of Skinner (1969) and Wheelwright (1984). On the other hand, the conceptual frameworks of

Azapagic (2003), Reich-Weiser et al., (2008) and Subic et al., (2012) on sustainable manufacturing failed to deal with the competitive function of manufacturing – the notion that manufacturing must create the capabilities of the organization.

Johansson and Winroth (2010) performed a plausible attempt in integrating these two approaches which explored the impact of stakeholders' concerns for the environment to the manufacturing strategy formulation process. The framework incorporates the insights of the works of Wheelwright (1984), Hayes and Pisano (1996) and Hallgren and Olhager (2006) and the stakeholders' interests described in sustainability literature. Johansson and Winroth (2010) emphasized that incorporating environmental issues alters the policy areas of all decision categories and requires environmental performance as a competitive strategy. The work culminates with guidelines and recommendations on the changes in policy areas of decision categories. Despite of this integration, the framework of Johansson and Winroth (2010) failed to holistically integrate sustainability and manufacturing strategy from various perspectives that have been known to influence manufacturing decisions, e.g., firm size, strategic stances, stakeholders' interests, etc. Thus, this paper provides a theoretical framework that advances the state of the art of knowledge in manufacturing strategy and sustainability. The theoretical framework is designed to cover the entire spectrum of these areas at a firm level. The objective is to propose a conceptual framework that links these two areas in an attempt to quantitatively determine the decisions that must be made in order to develop a sustainable manufacturing strategy. The contribution of this work is the integration of manufacturing strategy and sustainable manufacturing that guides manufacturing decision-makers in developing a sustainable manufacturing strategy.

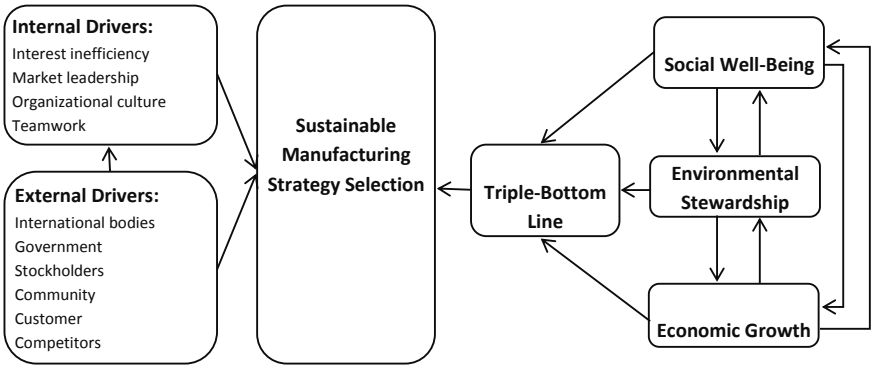
Sustainability

Sustainable development, as defined from the famous report of the United Nations World Commission on Environment and Development (WCED) in 1987, is "a development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (Brundtland, 1987). One potential key to the pursuit of sustainable development is sustainable manufacturing (Rosen and Kishawy, 2012). Manufacturing sector has a strong leverage on sustainability due to an inherent high volume of resource consumption, increasing number of new products that are introduced annually that relatively require high levels of energy and materials consumed and wastes generated. Manufacturing processes and their resulting products impose an adverse immediate impact on the community.

Efforts that address sustainable manufacturing at present could be divided into two major groups: (1) management, and (2) design and engineering. Management of sustainable manufacturing includes systems approaches, such as environmental collaboration in the supply chain (Zailani, et al., 2012), product life cycle assessment (Heijungs, et al., 2010), eco-design (Rosen and Kishawy, 2012), environmental purchasing (Zailani, et al., 2012), etc. Design and engineering efforts on sustainable manufacturing involve techniques and approaches that address materials, energy and wastes (Yuan and Dornfeld, 2009; Yuan, et al., 2012; Despeisse, et al., 2013; Smith and Ball, 2012). However, these two approaches at present detach themselves from competitive strategies of the firm. The link between these approaches and the internal and external functions of manufacturing in creating competitive advantages remains unclear.

One enabling factor toward sustainable manufacturing is the presence of stakeholders' interests. Sustainability is only achieved when interests of different stakeholders, such as the government, customers, suppliers, community, competitors, shareholders, employees and consumers, are satisfied (Theyel and Hofmann, 2012). A framework proposed by Ocampo and Clark (2014a) illustrates the role of stakeholders as drivers in selecting sustainable manufacturing strategy, as shown in Figure 1. This notion of satisfying stakeholders' interests along with the strategic activities of a manufacturing firm promotes complexity in decision-making over various decision areas such that a relevant framework must be available to provide guidance in addressing this complex scenario.

Figure 1: Sustainable manufacturing strategy selection framework



Source: Ocampo and Clark (2014a)

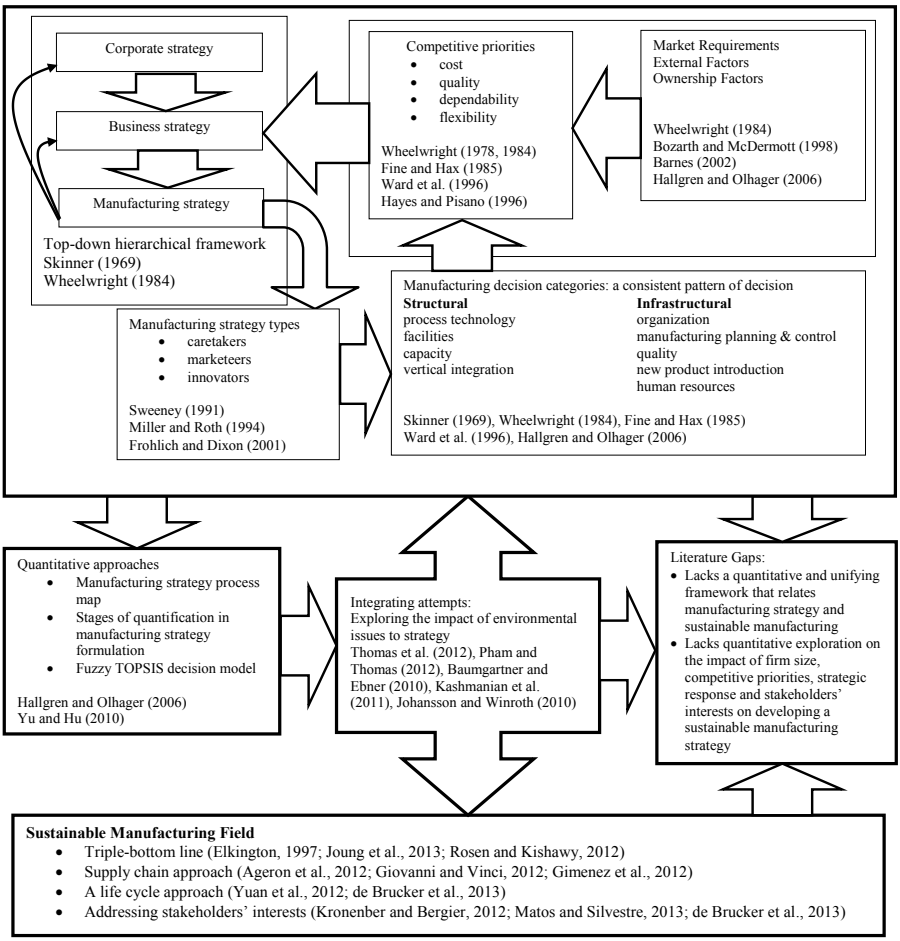
Theoretical Framework

From these approaches, a theoretical framework could be structured from the prominent theories that are tested and validated by previous researches. These theories came from manufacturing strategy and sustainable manufacturing. Figure 2 shows the theoretical framework of this work. As indicated, these two fields seem to be disintegrated and significant attempts have been made to provide some links on these fields. The upper right-hand corner of the framework shows the top-down hierarchical framework proposed by Skinner (1969) and supported primarily by Wheelwright (1984). It shows that manufacturing strategy supports business strategy and business strategy supports corporate strategy, as well. The feedback loops of manufacturing strategy to business and corporate strategies were proposed by Fine and Hax (1985) and Pun (2004) and supported empirically by Ward et al. (1996) and Gonzalez et al. (2012). These loops provide mechanisms that would update both levels of strategies regarding the status of the manufacturing function.

Manufacturing strategy had been known to have generic types and each type has, to a certain extent, particular sets and policy areas considered in making manufacturing decisions. These generic types of manufacturing strategy were comprehensively reviewed by Sweeney (1991) but were popularly known in 1994, following the work published by Miller and Roth (1994). Further evaluation and support was done by Frohlich and Dixon (2001),

following the similar taxonomies with Miller and Roth (1994). Taxonomies were classified as caretakers, marketeers and innovators. A particular manufacturing strategy type forges a set of policies that characterizes manufacturing decision categories. Consistency was achieved in literature

Figure 2: Theoretical Framework



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regarding the types of these decision areas. These areas can be categorized into structural and infrastructural categories (Wheelwright, 1984; Hallgren and Olhager, 2006). Consistent pattern of decisions over these nine decision categories would develop a set of manufacturing capabilities or competitive priorities, which is also consistent with the business strategy. Works of Wheelwright (1978; 1984), Fine and Hax (1985), Ward et al. (1996)

and Hayes and Pisano (1996) are consistent with the four competitive priorities: cost, quality, dependability and flexibility. Ocampo and Clark (2014b) were able to show that a mix of these competitive priorities has an impact to firm sustainability. Additionally, by varying priorities of these competitive capabilities, manufacturing firms can make a trade-off on sustainability dimensions (Ocampo and Clark, 2014b). The set of competitive priorities a business strategy determines came from market requirements and some external factors. For instance, in a semiconductor manufacturing industry where quality is mostly the objective of the market followed by flexibility, dependability and cost, business strategy must aim to address this market requirement. Thus, the manufacturing function must make decisions to support this requirement and at the same time provides an opportunity for a competitive position in the market.

The second part of the framework introduces the field of sustainable manufacturing. Some important concepts are relevant in this field. For instance, the triple-bottom line approach embodies the framework of sustainability (Elkington, 1997). Manufacturing products and process must not harm the environment and the society and at the same time must be economically sound. These three areas, i.e., environment, economy and society, must be simultaneously considered so that sustainability is achieved. A manufacturing organization is hardly sustainable if upstream suppliers and downstream customers are not placed in the equation (Ageron, et al., 2012). Materials, energy and wastes must be critically analysed throughout supply chains, not on individual manufacturing plants alone. This enhances collaboration and some economy of scale with regards to the efforts of manufacturing firms in driving toward sustainable manufacturing. Likewise, product and process design for sustainability must be considered throughout the product's life cycle stages (Yuan, et al., 2012). Environmental and societal impact of the product and its manufacturing processes must not be contextualized within manufacturing gates alone, but must extend from cradle to grave so that all stages are considered. Lastly, following the notion of triple-bottom, considerable effort has been placed with regards to research on the impact of stakeholders' interest to sustainability of manufacturing firms (Theyel and Hofmann, 2012; Matos and Silvestre, 2013; de Brucker, et al., 2013). Theyel and Hofmann (2012) emphasized that aside from pressures imposed by stakeholders on the firm, stakeholders, on the other hand, help manufacturing firms in decision-making, especially on environmental and societal issues through their perspectives, experiences and resources. These approaches of a triple-bottom line, supply chain and product life cycle perspectives and stakeholder approach constitute a systems approach to sustainability which analyses sustainability in wider and more inclusive viewpoints.

Hallgren and Olhager (2006) provided significant advances in manufacturing strategy field by introducing a quantitative framework in formulating a manufacturing strategy. However, the framework fails to consider the impact of sustainability issues in the formulation of a manufacturing strategy. Significant attempts were done in linking the two fields, such as the works of Thomas et al. (2012), Pham and Thomas (2012), Baumgartner and Ebner (2010) and Kashmanian et al. (2011). The most commendable framework that relates the frameworks of Skinner (1969) and Wheelwright (1984) to sustainable manufacturing was proposed by Johansson and Winroth (2010). Their notion could be summarized into two forms: (1) to embed environmental concerns into manufacturing strategy, environmental performance should be a competitive priority, and (2) when environmental issues are to be linked with manufacturing strategy, manufacturing decision categories would be al-

tered to accommodate policy areas that would be aligned to environmental performance. However, the framework of Johansson and Winroth (2010) lacks a quantitative approach in modelling decisions when sustainability concerns are to be considered. Upon review of the connecting concepts of the theoretical framework, significant research gaps are known. Current knowledge lacks a quantitative unifying framework that systematically integrates sustainable manufacturing and manufacturing strategy fields. Using quantitative models, the framework must provide insights on how decisions must be made in developing a sustainable manufacturing strategy. This framework would attempt to explore several issues, such as the impact of firm size, competitive priorities, strategic response and stakeholders' interests on developing a sustainable manufacturing strategy.

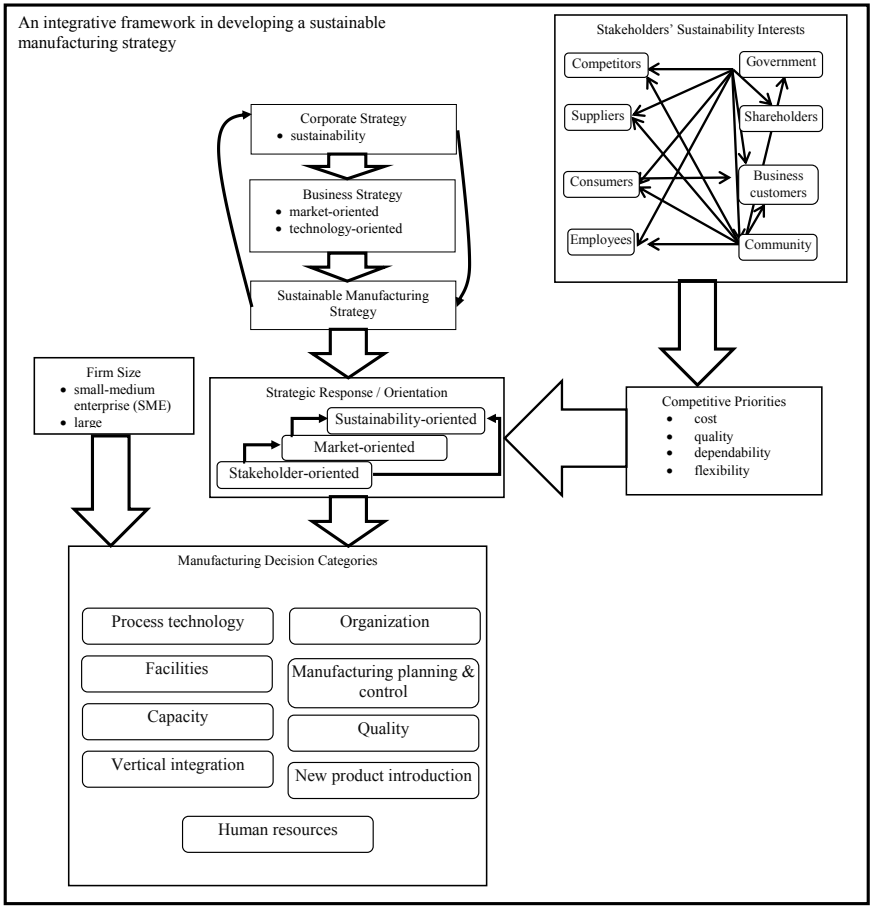
Conceptual Framework

Since current literature provides limited information on the integration of manufacturing strategy and sustainable manufacturing, this paper provides a conceptual framework that quantitatively links these two fields. The framework systematically integrates important concepts of manufacturing strategy and sustainable manufacturing, with the goal of effectively providing comprehensive guidelines about making decisions in developing a sustainable manufacturing strategy. The conceptual framework proposed in this paper is shown in Figure 3.

The first part of the framework incorporates the top-down hierarchical approach of Skinner (1969) and Wheelwright (1984), relating corporate, business and manufacturing strategies. Embedding sustainability in an organization requires top management support and, thus, the drive to embrace it must come from corporate directives. For instance, in a semiconductor manufacturing industry, the decision of aligning manufacturing operations and products with EU's directives on Restriction of Hazardous Substance (RoHS) and Waste Electrical and Electronic Equipment (WEEE) must be motivated from top management. Otherwise, support on resources and pertinent manufacturing policies would likely fail. Aside from the top-down approach of Skinner (1969) and Wheelwright (1984), the framework also incorporates the feedback loops introduced by Fine and Hax (1985) and Pun (2004). Business strategy is classified as market-oriented and technology-oriented and this orientation would have an impact to the decisions made by the manufacturing function. Technology-oriented business approach tends to focus on decisions that advocate advanced process technologies in order to lead technological innovation. Market-oriented approach, on the other hand, explores what satisfies customers and how they could be addressed by manufacturing decisions. Unlike with the former taxonomies on manufacturing strategy, the proposed framework integrates former taxonomies, such as caretaker, marketeer and innovator (Miller and Roth, 1994) and with the orientation of the firm toward sustainability (Johansson and Winroth, 2010). With this, three strategic responses are identified, such as stakeholder-oriented, market-oriented and sustainability-oriented, and these responses are arranged in an increasing degree of acceptance on sustainability approaches. Similar with the routes defined by Sweeney (1991), the framework introduces two routes on sustainability: the first one is the stakeholder-oriented → market-oriented → sustainability-oriented route, and the second one is the stakeholder-oriented → sustainability-oriented route. Each of these strategic responses would characterize a set of manufacturing decision categories. The framework maintains the nine (9) decision areas, but also incorporates the insights of

Johansson and Winroth (2010) on the impact of sustainability issues on decision categories. Unlike with former approaches that consider decision areas as independent of each other, the proposed framework considers causal relationships of these areas. For instance, the direction of vertical integration, either upward or downward supply chain, would have an impact on the structure of the organization.

Figure 3: Conceptual Framework on Formulating Sustainable Manufacturing Strategy



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Unlike former notions that manufacturing strategy and business strategy are motivated by market requirements, a sustainable manufacturing strategy must incorporate the interests of different stakeholders, as described by Theyel and Hofmann (2012). These interests impact the strategic responses of manufacturing firms toward sustainability. For instance, demanding interests of government, such as in regulations, policies, penalties and

taxes, with increasing demands of customers and consumers could motivate manufacturing firms from a stakeholder-oriented stance to a market-oriented stance. This implies another set of decisions in different manufacturing decision areas.

The interaction of stakeholders' interests also frames the set of competitive priorities that must be satisfied by the manufacturing decisions of the firm. Thus, decision categories are not only affected by the strategic responses of firms, but are also motivated by the set of competitive priorities developed by this interaction. For instance, increasing environmental government regulations could enforce quality as the competitive priority of an industry. To address this priority, manufacturing firms must make a pattern of decisions that would improve monitoring of the environmental impact and performance of products. Furthermore, firm size could have a significant impact on these manufacturing decision areas. Small and medium enterprises (SME), with constraint primarily on the amount of resources available, would certainly make different decisions compared to the large company counterpart. The conceptual framework, as shown in Figure 3, could provide significant and interesting insights: (1) the sustainable manufacturing strategy has its foundation on supporting the competitive advantage of the firm, (2) the framework extends the traditionally market-perspective of strategy to a holistic approach which incorporates the interests of stakeholders to address sustainability, (3) stakeholders' interests are not independent but are allowed to interact, which happens in actual cases, (4) the framework explores the impact of firm size, providing opportunities to researchers and practitioners to take a look how this factor impacts manufacturing decisions and, eventually, a sustainable manufacturing strategy, (5) it also explores the impact of strategic responses of manufacturing on sustainability, creating a template of strategic responses to manufacturing decisions, (6) it also provides an opportunity to explore the relationship of competitive strategies and decision areas, and, (7) lastly, the framework is able to formulate a sustainable manufacturing strategy that is grounded on manufacturing strategy and sustainable manufacturing.

Conclusion

This work progresses knowledge in two ways: (1) development of a sustainable manufacturing strategy and design of sustainability program based on consideration of both manufacturing strategy and sustainable manufacturing fields, and (2) development of a framework used to guide decision-makers in sustainable manufacturing strategy development with relevant issues, such as firm size, competitive priority, strategic response and stakeholders' interests. Specifically, interesting insights are the following ones: (1) the sustainable manufacturing strategy supports the competitive advantage of the firm, (2) the framework extends the traditionally market-perspective of strategy to a holistic approach which incorporates the interests of stakeholders to address sustainability, (3) stakeholders' interests are not independent but are allowed to interact with each other, which happens in actual cases, (4) the framework explores the impact of firm size which other researchers failed to consider, (5) it also explores the impact of strategic responses of manufacturing on sustainability, (6) it also provides an opportunity to explore the relationship of competitive strategies and decision areas, (7) the conceptual framework relates a sustainable manufacturing strategy to best practices developed today. Several studies could be extended from this framework: (i) empirical studies using factor analysis or structural equation model-

ling (SEM) must be conducted to test the validity of the proposed framework; (ii) development of a content sustainable manufacturing strategy using multi-criteria decision methods (MCDM) is seen as a fruitful work which creates a set of decisions on key manufacturing decision areas. A promising MCDM framework that holistically captures uncertainty in group decision-making was presented by Ocampo and Clark (2014c); (iii) optimization studies using multi-objective techniques of allocating firm's resources on the resulting manufacturing decisions; and (iv) sequencing of firm's strategic decisions using artificial neural networks or meta-heuristic algorithms.

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SIŪLOMA TVARIOS APDIRBAMOSIOS GAMYBOS STRATEGIJOS STRUKTŪRA

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Santrauka. Dabartiniai metodai ir iniciatyvos, bandant spręsti tvarumo klausimą apdirbamojoje gamyboje, stokoja aiškios krypties teikiant pagrįstus sprendimus pagrindinėse gamybos sprendimų srityse. Iššūkis slypi diegiant tvarumą į įprastą konkurencinę gamybos įmonių orientaciją. Taigi, šiame straipsnyje siūloma tvarios apdirbamosios gamybos strategijos struktūra, kuri yra grindžiama tvarumu nepamirštant vidaus ir išorės gamybos sistemos konkurencingumo funkcijų. Siūloma struktūra bando integruoti klasikines apdirbamosios gamybos strategijos teorijas ir dabartinį tvarios apdirbamosios gamybos poreikį, stengiantis suformuoti tvarios gamybos strategiją, kuri apibūdina dvi skirtingas apdirbamosios gamybos funkcijas: konkurencingumą ir tvarumą. Struktūros aktualumas glūdi jos galimybėje būti kiekybiškai ištirta naudojant įvairias priemones, pvz., taikant daugiakriterį sprendimų priėmimo metodą. Skirtingų komponentų struktūros aspektai ir ryšiai pateikti šiame straipsnyje. Šio darbo indėlis yra tvarumo ir apdirbamosios gamybos strategijos integravimas į holistinę sistemą, kuri pabrėžia tvarumo ir konkurencingumo funkcijas apdirbamojoje gamyboje.

Reikšminiai žodžiai: apdirbamosios gamybos strategija, tvari gamyba, struktūra.