Sustainable Design-Centered Manufacturing

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Abstract – This paper illustrates a new manufacturing capability which is driven by design and sustainability. Several successful design cases which have used or have been waiting for the insertion of new manufacturing technologies have been discussed. The cases of these worldwide leading products or systems include Kazuo Kawasaki eyeglasses, Mac iBook, Boeing 787-8, integrated circuits, plasmafication, and information-based medicine. The research also forecasts the value increased by the activities of design-centered manufacturing. After defining the scope of sustainability, an analysis of a strategy of a sustainable organization is also included. The research results predict that the competitive advantages of new products come not only from the advanced manufacturing technologies but also from a sustainable design-centered manufacturing approach.

Keywords – Sustainability, Design-centered, Technology insertion.

I. INTRODUCTION

The leading manufacturing capability will generate competitive advantages for the local economy. The goal of a national manufacturing strategy would be to create the most competitive environment for manufacturing firms to flourish. For instance, a typical example is that Japan invests $2 billion annually in its Koshsetsuhsi Centers, which is similar to Manufacturing Extension Partnership (MEP) in the U.S. [1]. The global trend for the manufacturing market transformation has been studied by Simchi-Levi, et al. [2]. Figure 1 forecasts the change of the local demand and supply of the manufacturing industry in the world from 2010 to 2013. Meanwhile, Asia will increase 6% and North America will decay 7%.

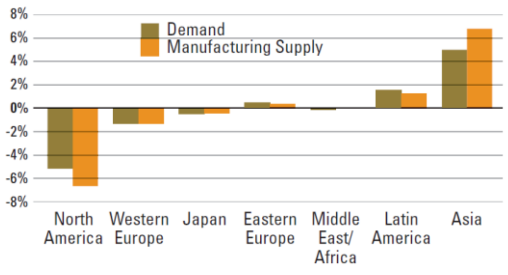

Fig. 1 Projected change in regional share from 2010 to 2013[1].

However, as per Figure 2, the variation for the local demand and supply is in the range of 5 % to 10 % in the different area of the world. Figure 2 describes a forecast of the location of manufacturing operations related to the company's revenues for companies with more than $10 billion in revenue in 2012. It looks like that demand and supply of manufacturing will stay in the local area but may be transformed and dependent on the local competitive advantages of manufacturing capability.

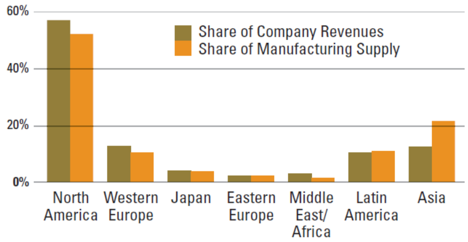

Fig. 2 Location of manufacturing operations vs. company revenues for companies with more than $10 billion in revenue in 2012 [2].

This paper explores the next generation of the competitive advantages of manufacturing capability in the world and how to generate the values from advanced manufacturing technology through a new concept of sustainable design-centered manufacturing. This research uses the triangulation method of the qualitative analysis. First, the research justified that design-centered manufacturing gained competitive advantages on the market, and then defined the scope of sustainability in the following sections.

II. DESIGN-CENTERED MANUFACTURING

The basic concept of Design-Centered Manufacturing is that research for new manufacturing technologies strives to fit advanced design needs in the product development cycle. The synergy comes from the innovation of new product development through completely mutual communication between design and manufacturing and applies the innovative manufacturing technologies to fit design requirement. For example, Taiwan Semiconductor Manufacturing Company (TSMC) has developed a similar model of the cooperation between design and manufacturing. The model is shown is Figure 3 [3].

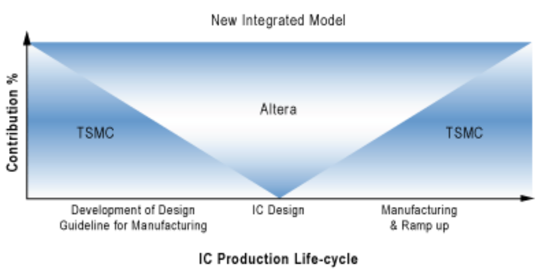

Fig. 3 A new integrated model for IC production life-cycle [3].

In this figure a new integrated model between TSMC and the Integrated Circuits (IC) Design Co., Altera, has been successfully developed. TSMC plays an important role for the development of design guidelines for manufacturing in the design phase of the IC chips. Through the new technology insertion from TSMC's manufacturing capability, Integrated Circuit (IC) design may change.

Another typical example is Kazuo Kawasaki eyeglasses. A product of these eyeglasses is shown in Figure 4. The design of Kazuo Kawasaki glasses utilizes several new manufacturing technologies, such as Beta Titanium Metal Forming and Welding, Multi-lens Molding, Physical Vaporized Deposition, Plastic Injection Modeling, and Mass Customization. The new design of this pair of glasses has replaced the concept of the old design of eyeglasses and has doubled its brand value on the market.

Fig. 4 Kazuo Kawasaki eyeglasses [4]

In order to justify the concept of design-centered manufacturing, the research analyzed four successful products and two systems. A summary of technology insertion used in these products is illustrated in Table 1. Table 1 also shows that sustainability will be a need for plasmafication for waste to energy and information-based medicine for healthcare.

TABLE I
TECHNOLOGY INSERTION FOR SOME DEMAND PRODUCTS

Product	**Demand**	**Technology insertion**
Kazuo Kawasaki Eyeglasses	Lightweight	Beta Titanium Metal Forming and Welding
		Multi-Lens Molding
		Physical Vaporized Deposition
		Plastic Injection Modeling
		Mass Customization
Mac iBook	Thin, Easy	PCB Frame Manufacturing
		Magnesium Manufacturing Technology
		User Friendly Software
Boeing 787-8	Lightweight	Carbon Fiber Manufacturing
		Health-Monitoring Embedded
		One-Piece Fuselage
Integrated Circuit	Small, Fast	Chemical Etching Technology
		Concurrent Engineering
Plasmafication	Safety	Leachability
	Sustainable	High Temperature Material Handling Process
		Toxic Gas Handling Process
		Toxic Materials Metallurgy
Information-Based Medicine	Safety	Information Correlation
	Sustainable	Automated System
		Nanotechnology

The estimate of the values increased in these new products and systems are depicted in Table 2.

TABLE II
Product value added through sustainable design-centered manufacturing

Product	**Value Increased**
Kazuo Kawasaki Eyeglasses	x 3 [4]
Mac iBook	x 2 [5]
Boeing 787-8	x 1.5 [6]
Integrated Circuit	Beyond Moore's Law [7]
Plasmafication	Waste to Energy x 0.7 [8]
Information-Based Medicine	Human Life + 50 [9]

III. SUSTAINABILITY-BASED INNOVATION

The wave of innovation may shift from Internet and Information Computer Technology (ICT) to sustainability in the 21 century. In this section the author surveyed the definitions and the scope of sustainability and studied the major metrics for performance evolution of the sustainability in terms of the management of an academic organization. This offers a hint of the concept of sustainable design-centered manufacturing for future research.

A. Waves of innovation

The change of waves of innovation for the last two hundred years is described in Figure 5.

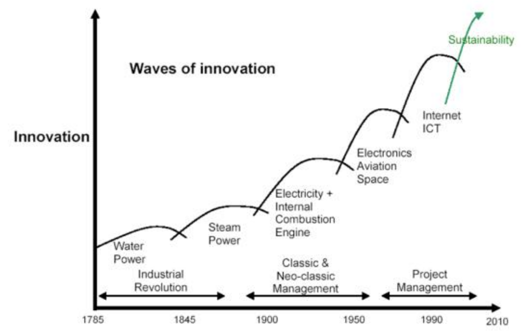

Fig. 5 Waves of innovation [10]

According to Hargroves's research, the next wave of innovation will be sustainability [10]. Nevertheless, Hargroves did not clearly define the major issues for the future system transformation in organizations. According to my above research, sustainable design-driven manufacturing will be the new product development process. The scope of sustainability will be based on this new process in one organization or across multiple organizations. In the following paragraph, the macro scope definition of sustainability and a practice case in terms of the metrics of performance evaluation for sustainability in organizations will be discussed.

B. Definitions of Sustainability

The different definitions of sustainability historically are illustrated as follows:

1) Brundtland Commission, 1987:

"Sustainable development is development that meets the needs of the present without comprising the ability of future generations to meet their own needs."

2) Stephen Viederman, 1993:

"…to ensure to the degree possible that present and future generations can attain a high degree of economic security and achieve democracy while maintaining the integrity of the ecological systems upon which all life and production depend. …"

3) Alan AtKissin, 1998:

"Sustainability is an ideal end-state. Like democracy, it is a lofty goal whose perfect realization eludes us."

The goal of a sustainable society includes three components. They are a flourishing economy, social health/social justice, and a sound environment. Construction of a sustainable society is based on a tradeoff process among economic, social, and environmental issues as shown in Figure 6 [11].

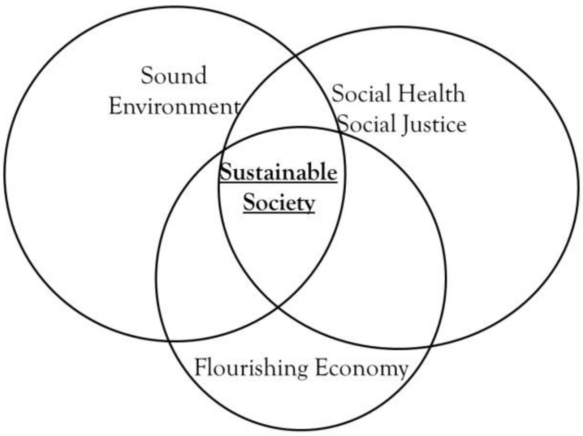

Fig. 6 Components of a sustainable future [11]

In order to understand the metrics of performance evaluation of sustainability, the author analyzed the contents in the Sustainability Tracking, Assessment & Rating System (STARS) developed by the Association for the Advancement of Sustainability in Higher Education (AASHE). The evaluation items and points are shown in Figure 7. Figure 7 is an evaluation of sustainability on American higher education campuses. It shows that curriculum development is an important factor for the growth of sustainability on campus. The summation of the points of curriculum, public engagement, and research occupies over 1/3 of the total points. This shows that a sustainable design-centered manufacturing system needs highly human-centered management processes in the organization.

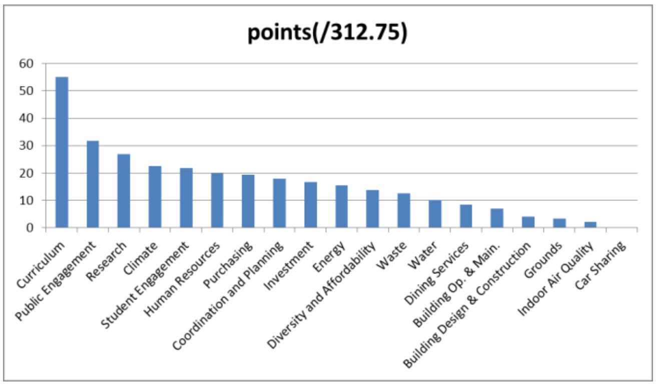

Fig. 7 Statistical results of sustainable metrics for STARS of AASHE

V. CONCLUSION

This research confirms that the trend of manufacturing capability will be a sustainable design-centered manufacturing approach as shown in Figure 8. The core competitive advantage of the local manufacturing industry will be based on the sustainability and designed-driven system when developing new products. This concept adheres to standards beyond the ISO14000 and Restriction of Hazardous Substance (RoHS) standards developed in 2005 in Europe. Water footprints and carbon footprints will be the typical metrics for sustainable design-centered manufacturing in the near future.

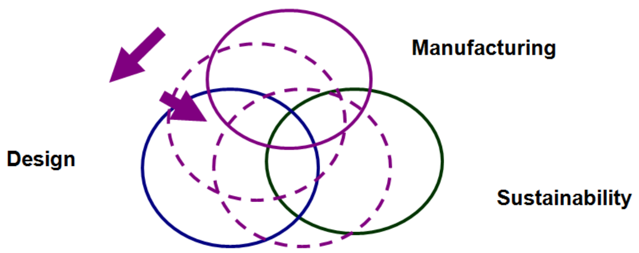

Fig. 8 Trend of manufacturing for design and sustainability

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