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Applying green manufacturing model to build sustainable competitiveness

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Abstract - **Global warming has revealed public awareness of environmental protection and motivated customers to request green products. Pressures can also create opportunities. As the enterprises face the fact and take a corrective action, those who best meet and find solutions to the challenge will lead the competitive pack. Given this trend, this paper presents a green strategy for building a green manufacturing model that connects production system and life cycle assessment required and injects green thinking into each stage of manufacturing process. This model drives original manufacturing system from a less green into a greener and more eco-efficient manufacturing. From the result of this case study, the model is an attempt to better explain green manufacturing and is no doubt a shot in the arm for companies to develop sustainable competitiveness.**

Keywords - **Green manufacturing, Global warming, Sustainable competitiveness**

I. INTRODUCTION

Global warming, which is caused by greenhouse gas emissions and is responsible for extreme weather in recent years, has attracted increasing attention from both governments and scientists around the world [1]. Global warming also reveals two potential pressures. First is that the limits of the natural world could constrain business operations, markets, and perhaps even threaten the planet's wellbeing. Second, companies start facing a rising percentage of customers who are concerned about the environment. For this reason, creating green products is becoming the green trend for customers and the earth. As the companies wake up and face the fact that many natural resources are finite, a reality is emerging in parallel: Pressures can also create opportunities. Those who best meet and find solutions to these challenges will lead the competitive pack [2].

Measuring the pollutions from manufacturing process includes several accounting categories that relates to the production and its original design. Especially, pollutions occur at all phases of a product's lifecycle, from resource extraction, to manufacturing, use and reuse, final recycling or disposal. For this reason, green manufacturing (GM) has played an important innovation that helps organizations develop green strategies that seek to achieve profit and market share objectives by reducing their environmental risks, while increasing their ecological efficiency.

Even though a hot wave in green manufacturing is increasing more and more no matter in research or in practical, many classifications are required to defined, especially, in different level such as green manufacturing practices and principles on the operation, process planning and system implementation. In other words, a clear definition of what is green manufacturing and how to develop green manufacturing is becoming more important. Furthermore the definition between traditional production and green manufacturing needs to be better explained to avoid confusion arises.

The goal of this paper presents an innovative green manufacturing model. The model connects production system and life cycle assessment (LCA) required and injects green thinking into each stage of manufacturing process. This model drives original manufacturing system from a less green into a greener and more eco-efficient manufacturing. The model is an attempt to better explain green manufacturing and is no doubt a shot in the arm for companies to develop sustainable competitiveness.

II. GREEN MANUFACTURING AS A COMPETING STRATEGY

In Michael Porter's competitive strategy model, companies gain competitive advantage by lowering costs or differentiating products. But today the traditional points of competitive differentiation are being squeezed on all sides [3]. Outsourcing strategy and lowing labor costs is easier to almost any companies, no matter, big or small. Other once unassailable sources of advantage, such as access to capital or low-cost raw materials, are disappearing as markets go global. Competitive advantages are becoming ever more difficult to establish and maintain.

Green strategy will play a critical role and offer just this sort of opportunity in obtaining market competitiveness. In the not far future, no companies will be positioned for industrial leadership and sustained profitability without melting environmental issues into its strategy [4]. Therefore, any company that expects to achieve and maintain sustainability over its competitors must seriously consider strategic planning for green manufacturing.

Green manufacturing evaluates all its new raw and packaging materials, manufacturing model, equipment, 3R mechanism, and finished products from an environmental perspective. The core concept for blueprinting a green strategic plan that was presented in this paper will not only formalize the process but also ensures that all opportunities are examined in pollution reduction and fit green issue.

Green manufacturing is the idea stage to address environmental concern. Product can obtain environmental profit only if they are manufactured to achieve environmental requirement. In addition, manufacturing process has significant impact on the quantity of pollutions generated at different stages of a product's life cycle [5]. A green manufacturing model must match laws and a variety of performance targets. In addition, it should lend itself to easy manufacture and assemble. Green manufacturing model can improve greenness by modifying either a product or whole product system including the manufacturing process, distribution, use, disposal, and maximum reduction in pollution [6].

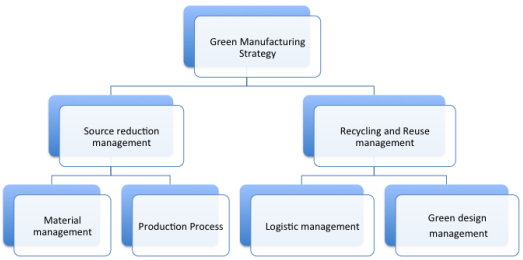

Fig. 1. Green manufacturing strategy.

Source reduction and Recycling and Reuse management are two broad types of green manufacturing principles (Figure1). Materials are major contributors of environmental degradation. Source reduction strategy eliminates pollutions at source level by using less material to perform the same operation. Therefore, any material reduction in production also can decrease waste and prevent environmental damage. The other principle is that better carbon management technique includes green design for 3R and logistic management.

Green manufacturing model in this phase is aimed at making products easy to manufacture, remanufacture recycle, compost, and incinerate. This strategy can also be applied in outsourcing. All the above actions take a co-work and control approach to greening your production system. This green manufacturing model can develop win-win solutions between environmental problems and organizational performance.

III. CONCEPTUALIZING GREEN MANUFACTURING MODEL BY LCA

Green manufacturing model in reducing environmental pollutions is generally efficient. After all, choosing raw materials and ecological manufacture has advanced impacts therefore also has potential to significantly reduce an environmental shock. Since all possible factors made from inputs, manufacturing processes, distribution, use, and disposal are calculated. Prevention is rather better than cure. By Green manufacturing model, companies produce less scrap and less pollution. In short, these green products are efficient, easy to assemble, easy to manufacture, and so on.

Under green manufacturing model, LCA is an important tool to apply. In recent years, Life-cycle assessment can be used for a variety of purposes such as automotive design, manufacturing system, and consumer product design [7]. Such an analysis can provide valuable information in whole process and also provide information about how to improve the green product. This research integrates green strategies and LCA to develop a green manufacturing model.

This paper presents four phases framework in developing green manufacturing model: the initiation phase, consisting of the problem and objective definition; second phase defines all inputs and solid, liquid, and gaseous wastes; the third phase is impact analysis, connecting inputs and outputs to real-world environmental problems; and, finally, the improvement phase, focusing on the overall green performance.

1.Green manufacturing Scoping

The first step in performing a life-cycle assessment is to identify the purpose of analysis. The assessment may be done to compare materials, products, or processes; compare resource use; train employees in waste reduction; develop policy; or educate the public. The studies could be product specific. The next step is to define the system boundaries. The system definition should include where the "cradle" starts and where the "cradle" ends. It should begin with material extraction and end with final disposal of the product. The system definition should also take into account the depth of analysis.

2. Green manufacturing Analysis

The purpose of life-cycle inventory analysis is to develop a model to account carbon emissions for all inputs and outputs during each stage in the life cycle. Typically, the system is broken down into six stages such as raw material extraction, raw material processing, manufacture, product fabrication, filling and packaging, assembly, distribution, use, reuse, maintenance, and recycle and waste disposal.

- Raw material acquisition includes extraction of raw materials from the earth, harvesting trees, and their transportation.
- The manufacturing stage includes a transformation process consisting of manufacture, fabrication, assembly, filling, and packaging.

- Use, reuse, and maintenance include energy consumption, storage, and consumption of a finished product.
- Use, reuse, and maintenance include energy consumption, storage, and consumption of a finished product.
- A recycle—waste-management stage includes energy consumption and environmental wastes produced during recycling and waste disposal.

3. Environmental Impact Analysis

The impact analysis evaluates the effects of resources and emissions identified in the green manufacturing analysis. Impact analysis is still in the early stages of development. It should take into account, however, environmental and human health impacts, resource depletion, and social welfare. Impact analysis typically consists of classification, characterization, and valuation.

4. Improvement

The emphasis of the improvement analysis is on the entire process of a product. The purpose of improvement is to find out opportunities to reduce energy and raw material consumption and carbon emissions. Life-cycle assessment highlights the seriousness and can thus help companies develop "green product”.

IV. CASE IMPLEMENTATION

The case study uses thin film transistor liquid crystal display (TFT LCD) as an example. The paper focuses on assessing green manufacturing effect in reducing environmental damage during the manufacturing, transport, use, and disposal of TFT LCD in relation to comparable traditional manufacturing effect. In order to evaluate the environmental damage measures across the manufacturing process, Figure2 shows the entire manufacturing process of TFT LCD. Simultaneously, this paper selects the Global Warming Potential indicators for investigating carbon footprints. In this section presents the results of the analysis.

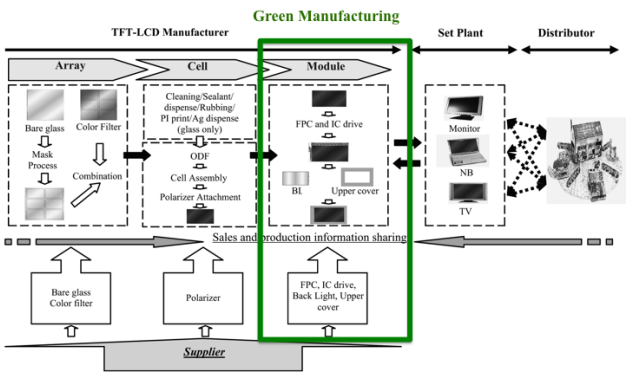

Fig. 2. Manufacturing process of TFT LCD.

The TFT LCD manufacturing process consists of hundreds of steps, but may be divided into three primary steps. The first step is the array process, which involves fabricating transistors on the back substrate using film deposition, lithography and etching. The second step is the cell process, which joins the back array substrate and the front color filter substrate. The space between the two substrates is filled with liquid crystal. The third step is the module-assembly process, which involves connecting additional components, such as driver integrated circuits and backlight units, to the TFT-LCD panel. But the array and cell processes are capital-intensive and require highly automated production equipment, this green manufacturing model will focus on module-assembly process. The Figure 3 shows these stages and the major steps contained within each stage. It should be involved that direct pollutions from the manufacturing process.

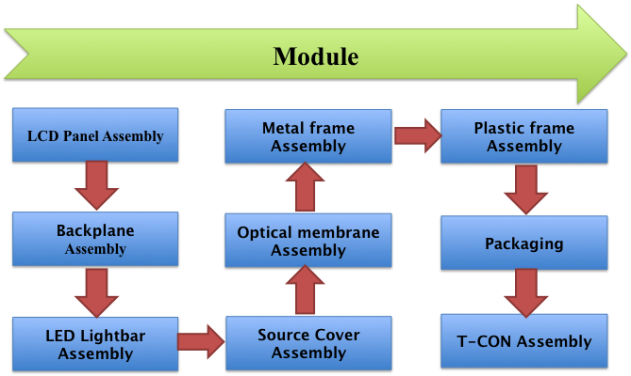

Fig. 3. Module process of TFT LCD.

The first check is to determine which process of the green manufacturing assessment is significant and which one is negligible from an environmental point of view. The following table 1 presents the simulation for each part of TFT LCD, broken down by these LCA stages. The table 2 presents the result after taking green manufacturing model.

TABLE I
PROPORTIONS OF THE ENVIRONMENTAL IMPACTS FOR TRADITIONAL MANUFACTURING

Indicator	FINITE	TOTAL	LCD Panel assembly	backplane assembly	LED Lightbar assembly	source cover assembly	optical membrane assembly	plastic frame assembly	metal frame assembly	Packaging	T-CON assembly
Global warming	Yes	1.5E+05	1.3E+02	1.1E+02	1.1E+01	1.7E+01	4.0E+01	4.0E+01	1.8E+00	5.5E+00	1.2E+00
Acidification	DATA	2.5E+02	1.1E+02	1.1E+02	2.0E+00	1.0E+00	1.0E+00	1.0E+00	0.0E+00	3.0E-01	4.5E-03
Eutrophication	DATA	2.5E+02	1.1E+02	1.1E+02	2.0E+00	1.0E+00	1.0E+00	1.0E+00	0.0E+00	3.0E-01	4.5E-03
Human toxicity	DATA	2.5E+02	1.1E+02	1.1E+02	2.0E+00	1.0E+00	1.0E+00	1.0E+00	0.0E+00	3.0E-01	4.5E-03
Photochemical oxidation	DATA	2.5E+02	1.1E+02	1.1E+02	2.0E+00	1.0E+00	1.0E+00	1.0E+00	0.0E+00	3.0E-01	4.5E-03
Ecotoxicity	DATA	2.5E+02	1.1E+02	1.1E+02	2.0E+00	1.0E+00	1.0E+00	1.0E+00	0.0E+00	3.0E-01	4.5E-03
Ozone depletion	DATA	8.0E+01	4.0E+01	3.5E+01	2.0E-01	2.5E-01	2.5E-01	4.0E-01	2.5E-02	2.5E-02	3.5E-02
Quality assessment	DATA	2.5E+02	1.1E+02	1.1E+02	2.0E+00	1.0E+00	1.0E+00	1.0E+00	0.0E+00	3.0E-01	4.5E-03
Consumer quality	DATA	1.8E+02	5.5E+01	5.5E+01	2.0E+00	2.0E+00	2.0E+00	1.0E+00	1.0E+00	1.0E+00	1.0E+00
Resource	DATA	9.5E+01	4.5E+01	4.5E+01	1.0E+00	1.0E+00	1.0E+00	1.0E+00	0.0E+00	4.5E-00	1.0E+00
Quality price	DATA	4.5E+00	1.5E+00	1.5E+00	1.0E+00	1.0E+00	1.0E+00	1.0E+00	0.0E+00	1.0E+00	1.0E+00
Consumer gift	TOTAL	2.5E+01	8.0E+00	1.0E+00	1.5E+00	1.5E+00	1.5E+00	4.0E+00	2.5E-02	2.5E-02	3.5E-02
Consumption/ production	TOTAL	3.5E+01	1.0E+01	4.5E+01	1.0E+01	1.0E+01	1.0E+01	1.0E+01	1.0E+00	1.0E+00	1.0E+00
Water use	TOTAL	1.2E+02	1.0E+02	8.5E+01	3.0E+01	4.0E+01	4.0E+01	4.0E+01	1.0E+00	3.0E-01	4.5E-03
Energy	TOTAL	1.0E+02	1.0E+02	8.0E+01	3.0E+00	3.0E+00	3.0E+00	3.0E+00	1.0E+00	3.0E-01	4.5E-03
Human health	TOTAL	1.5E+01	4.5E+00	4.5E+00	1.0E+00	1.0E+00	1.0E+00	1.0E+00	0.0E+00	1.0E+00	1.0E+00

TABLE 2
PROPORTIONS OF THE ENVIRONMENTAL IMPACTS FOR GREEN MANUFACTURING

Impact	UNITE	TOTAL	LCD Panel Assembly	Backplane Assembly	LED Lightbar Assembly	Source Cover Assembly	Optical membrane Assembly	Metal frame Assembly	Plastic frame Assembly	Packaging	T-CON Assembly
Climate change	Tradition way	1.80E-05	2.10E-06	7.20E-06	3.70E-06	8.30E-08	4.20E-06	2.00E-07	1.00E-07	2.50E-07	4.10E-07
Climate change	GM	1.24E-05	2.13E-06	1.37E-06	3.67E-06	8.28E-08	4.22E-06	2.00E-07	1.04E-07	2.51E-07	3.73E-07

According to the result, the methods used for reducing the carbon footprints of the TFT LCD include enhancing ecological efficiency and lowering the carbon footprints in specific process. Simultaneously, by the research result and reviewing relevant literature and technical reports, Figure 4 shows that a green manufacturing model of improving carbon footprints for TFT LCD is effective.

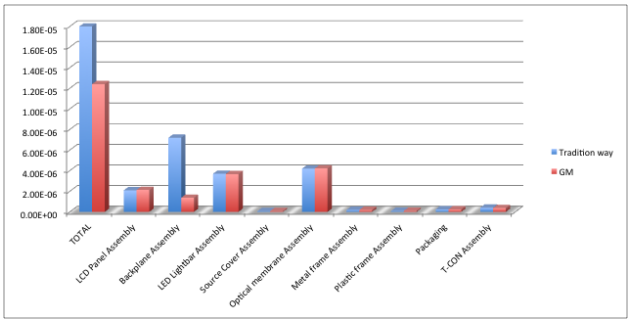

Fig. 4. The simulation results for two scenarios.

Global manufacturers face the challenge of reducing carbon emissions and preventing our earth. All manufacturers are responsible for designing and manufacturing the green products by reducing the carbon footprint. In addition, environmental shock includes four major scopes, such as resource impacts, air impacts, soil impacts, and water impacts. This paper takes carbon emission index as an example to explain the improvement from green manufacturing model.

The backplane assembly results a significant quantity of carbon footprints. If a consumer has to make a choice between a polluting and a nonpolluting product, he is likely to choose a nonpolluting one. Hence a manufacturer of a polluting product is likely to lose its market share in the long run. Therefore, substitution of polluting material with less polluting ones is a sensible strategy to reduce pollution and remain competitive. According to GM, this case changes manufacturing way of backplane assembly. Using the above strategies, this study divides the reduction of carbon footprints into two scenarios. The first scenario uses traditional manufacturing model, but the carbon footprint is higher. The second scenario replaces traditional one with green manufacturing model and produces low carbon footprints.

TABLE 3
COMPARISION OF TWO MANUFACTURING MODELS

V. CONCLUSION

Environmental issue makes many nations to build up laws and regulations for protection standards. Therefore, an effective manufacturing system can improve product quality, reduce pollution, and protect environment If companies focus significantly on reducing product pollutions, the performance will reflect on the reputation, brand and market share.

The proposed model for green manufacturing was demonstrated through a real case study. At the same time, the derived model was tested and simulated under two scenarios. The simulation results were showed to justify the cost-effective method to reduce the pollutions and provide data for strategic recommendations. According to the results, the green manufacturing model is appropriate for solving environmental questions and the proposed model serves as an adequate base for helping the companies to understand clearly the global effects of its decisions and encourages companies to realize pollution-prevention activities that need to be initiated.

This paper emphasis how to develop a green manufacturing model to produce green products and support enterprises convince their customers of the importance of environmental friendliness and product quality. Future work is ready to present the proposed real system model about structuring green implementation methodology and an evaluation framework. Finally, this green manufacturing model is able to apply in industrial case studies and helps companies to build green and sustainable competitiveness.

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