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DEVELOPMENT OF SCORE METRIC FOR SUPPLY CHAIN SUSTAINABILITY IN DESIGN PHASE

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ABSTRACT

Supply Chain is one of the stages of product lifecycle. This process evolves day by day through connected with other process of product development. The improvement of supply chain involve in many ways so that the effectiveness can be improve by minimizing time and cost. Sustainability is important issue need to be considered in supply chain process. Through sustainability, the environment, social and economic become the issues that can be further improved. There are a lot of factors in these three aspects of sustainability can be influence the process of supply chain by identifying and managing those factors in the design phase. However, the current technique of design phase did not give a lot of attention on sustainability issues in the supply chain that may effect the time and cost in product development process. Through this paper, a review of literature including a total design as a design model, supply chain and other supporting models and techniques will be discussed in order to integrate of sustainability, supply chain and design phase. This paper at the end prepare the general framework which will give a brief picture of integration the design phase and supply chain for this research in the development of score metrics for supply chain sustainability.

Keywords: supply chain, design phase, sustainability, product lifecycle.

INTRODUCTION

The management of product lifecycle itself is defined as an integrated, information-driven approach to all aspects of product life from its design through manufacture, deployment and maintenance- culminating in the product removal from service and final disposal (Grieves, 2006). Life cycle engineering aims to integrate issues and parameters into product development throughout the life cycle of a product, taking into account the requirements of long-time usage and recycling (Westkämper, 2003).

Product developments provide many ways of decision method during the lifecycle stage. The idea and planning about the product can be managed efficiently for the following stages. Through product development, some stages can be improved in order to achieve desired results. There are a lot of research being done to tackle this with the developing of assessment method to predict the performance for some stage like manufacturing, product sales, customer need, product service and product end-of-life (EOL).

Supply chain is another stage in product lifecycle involving the activities of product design till product reach the customers. Supply Chain Management is recognized as the network connection of interconnected business that form tight linkage among raw material, resources, production, transportation and distribution of material resources, information and financial flows for ultimate provision of goods and services (Wang and Gupta, 2011). The product development process (PDP) is one of the business processes of SCM (Handfield and Nichols, 2002). Sustainability issues appeares in many process of engineering. Hence, research is olso ongoing to provide solutions of sustainability in design aspect. Sustainability provides three dimension involving environmental sustainability, social sustainability and economical sustainability under the trade-off condition between them as represented in Figure-1. Tingström (2007) argued that the inclusion of environmental aspects in product development leads to increase in the number of design parameters and design uncertainty about the selection of design solution. Because of that, the supporting system through product development must be concerned on the aspect of environment.

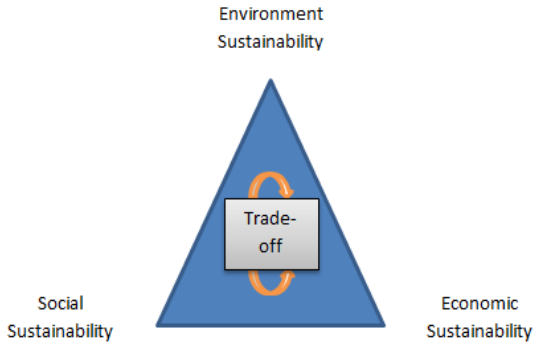

Figure-1. Three dimension of sustainability (Zarandi, Mansour, Hosseinijou, and Avazbeigi, 2011).

Recently, work on indicators for sustainability was introduced in order to monitor and control sustainability issue in engineering. Lu *et al*. (2011) introduced a framework of product and process metrics for sustainable manufacturing. Parris and Kates (2003) indicates over 500 efforts has been devoted to developing the quantitative indicators of sustainable development. Hence, the work in this paper will contribute towards providing indicators for sustainability especially in the area of supply chain sustainability.

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Prescriptive model

Product design is the detailed design phase which constitutes the specification of design parameters, precedence relations in product assembly, and the detailed design of the components including materials and process selection (Krishnan and Ulrich, 2001). In general, certain key-words and phrases can be noted which have a strong bearing on design include: needs, requirements, solutions, specifications, creativity, constraints, scientific principles, technical information, function, mapping, transformation, manufacture and economics (Evbuomwan, Sivaloganathan, and Jebb, 1996).

Design model provide two types of philosophies involving the prescriptive and descriptive model. Total design is the prescriptive model introduced by Pugh. Total Design may be defined as the systematic activity necessary from market/user need to the selling of a successful product to satisfy that need (Pugh, 1991). This research will be used total design as part of design framework. In general, total design approach to new product development provides a systematic, yet flexible, framework for new product development. The method also increases the possibility of market success through improved time to market and customer satisfaction.

Figure-2 shows a model of total design introduced by Pugh as the activity started from market research until product sell to customer. In this model, some important stage including product specification, conceptual design, detail design and manufacturing process are considered some other elements and processes also need to consider between these stages so that the framework produced the desired result at the end.

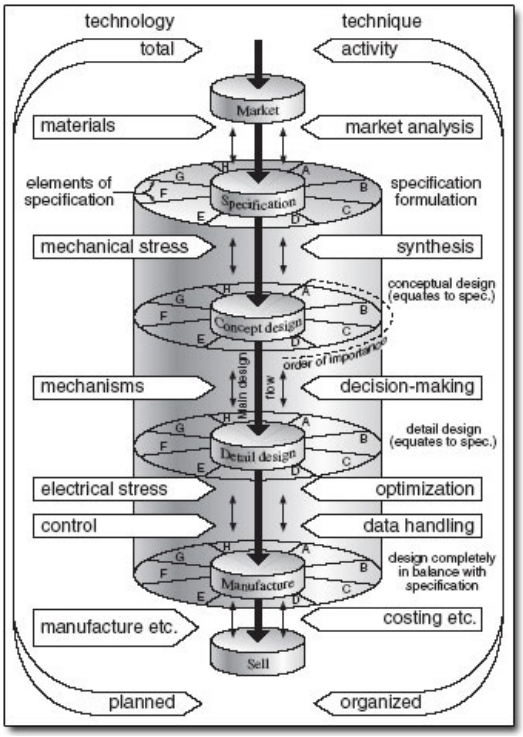

Figure-2. The total design activity.

Supply chain sustainability (SCS)

Supply Chain Sustainability (SCS) is the term for multidisciplinary system use of sustainability in the supply chain model. Supply chain is an integrated process wherein raw materials are converted into final products, the delivered to customers. At its highest level, supply chain is comprised of two basic, integrated processes of the production planning and the inventory control process, and the distribution and logistics processes (Beamon, 1998). There are a lot of challenges to slot the idea of sustainability especially for the environmental part in this system. Currently, there are still less effort to develop and combine the elements of sustainability for supply chain activity with design phase in order to minimize the aspects of cost and time using sort of assessment like score metrics.

Figure-3 shows the basic flow of SCM pipeline. SCM pipeline can be composed of a variety of players, each providing a range of specialized functions (Ross, 2010). Using this model, many operation stages need to go through with the best networking information recorded. The design of supply chain networks is a topic of engineering importance since it involves the determination of both the sites and the levels of operation of the relevant facilities that enables the manufacture, storage and delivery of product to consumers (Nagurney and Nagurney, 2010). The environmental is one of the information which should be considered, while the other two elements of sustainability namely social and economic should also be given attention.

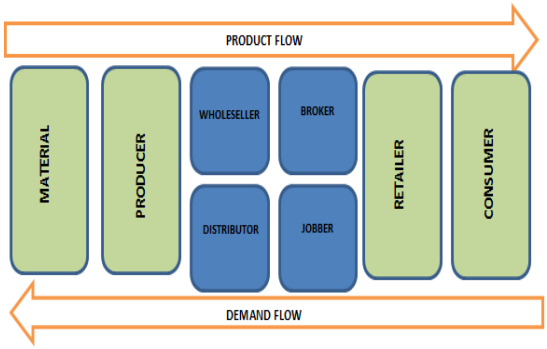

Figure-3. SCM pipeline (Wang and Gupta, 2011).

Due to environmental consciousness, the European Community introduced Waste Electrical and Electronic Equipment Directive (WEEE) and Restriction of Hazardous Substances Directive (RoHS) as a regulation to follow. These two directives concern, respectively, the RoHS in environment and the recyclability of WEEE (Gehin, Zwolinski, and Brissaud, 2008).

There are 46 influencing factors of sustainability mentioned by Gupta *et al*. (Gupta, Vangari, Jayal, and Jawahir, 2011) in the form of metrics in four stages of product lifecycle under pre-manufacturing, manufacturing, use, and post-manufacturing. All these stages become important to maximize the production and minimize the negative impact on triple bottom line-social, economic and

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environmental. Lu *et al*. (2011) present a framework for developing comprehensive product and process metrics for sustainable manufacturing, using machined products and machining processes examples, and addressing all three aspects of the triple bottom line.

By considering all aspects on the issue of sustainable in environmental, societal and economic, the important factor on supply chain activity was identified. For environmental sustainability, toxic waste, high greenhouse gas emissions and energy use are the factors under consideration. For societal factors, the labor issue on safety, health and ergonomics will be considered while for economic sustainability will concentrate on the cost of materials, and impact on fuel prices. All these issues will have an impact on supply chain activities and thus can be improved in order to minimize the cost and maximize the production.

Proposed framework

Supply Chain provides a good system for product development stage. Operation system in supply chain can be improved by minimizing the inefficiencies to make it more environmentally sustainable (Corbett and Klassen, 2006). The issue of social and economics should be given attention too as sustainability integrate all three factors. Figure-4 shows the framework combination of supply chain and the total design activity. This framework develops the supply chain process under design perspective.

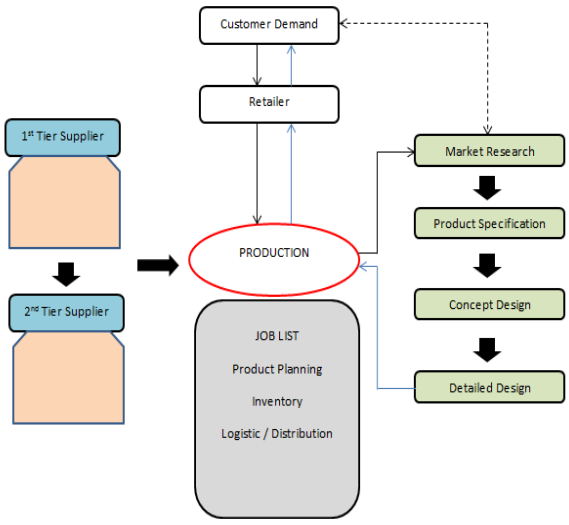

Figure-4. Design phase in supply chain framework.

This framework involves the design stages link to production or manufacturer. The idea to build this framework is to have a good view of supply chain from the design stage so that the assessment can be developed to link these two ideas. The supportive system is important because its recognize activity of supply chain in every stage and the tools can be used in different stages.

Enterprise Resource Planning (ERP) is supporting system that can be used in order to link the one producer with the supplier. ERP system has their own important component consist of people hardware, database, model base and processes (Goyal, 2011). Product Data Management (PDM) will be the supportive system of the total design activity while Customer Relationship Management (CRM) will link the producer to customers. CRM is the core business strategy that integrates internal processes and functions, and external networks, to create and deliver value to targeted customers at a profit. It is grounded on high quality customer-related data and enabled by information technology (Buttle, 2008).

In developing the supply chain score metrics, the tools can be used in all stages identified. Lifecycle analysis is the tool used in the overall framework as it analyzes the lifecycle of the product development. Material degradation will be used on the stage involving material where the analysis will concentrate on the amount of material reduction until the product arrives to customer. Besides, the Quality Function Deployment (QFD) can be used as a product/system development tools to obtain effective sustainable supply chain (Buyukozkan, 2010). The supply chain process finally will be analyzed using the bullwhip effect so that it can be compared to the current supply chain without sustainable attachment. To use all these tools the Design for Sustainability (DfS) will be the major reference as the assessment will be used on early design stage.

Integrate product design and supply chain sustainability

This research generally tries to collaborate the issue of sustainability in supply chain from the design perspective. The score metrics will be developed to integrate all 3 factors as in Figure-5. Sustainability in SCM must also include product design, manufacturing by-products, by-products produced during product use, product life extension, product end-of-life, in addition to core supply chain activities (Linton, Klassen, and Jayaraman, 2007).

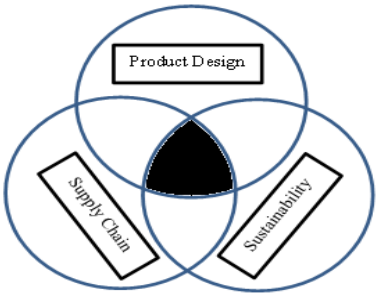

Figure-5. Score metrics of sustainability supply chain in design phase.

Product design plays an important role in shaping a firms supply chain and in guiding its eventual behavior (Park, Ogawa, Tatsumoto, and Hong, 2009). The supply chain (or supplier) must meet the needs of the product (or

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customers) and therefore its design should be based on the product characteristics that determine its customer needs (Marsillac and Roh, 2014). On the other hand, the product which satisfied the need of customer can also be linked to the design stage through the process of supply chain. These researches try to contribute on the design stage by determining the supply chain application using score metrics of sustainability.

To get a concrete view of sustainability factors in supply chain, the survey method will be used on the real supply chain in industry. The objective of the survey is to find the top sustainability issues in the supply chain activities and the effect on the operational supply chain.

To develop the score metric of sustainable supply chain, the analysis will rely on Artificial Neural Network (ANN) and Artificial Bee Colony (ABC). ABC algorithm was inspired by the foraging behavior of honey bees was proposed by Karaboga in 2005 (Karaboga, 2005). These two algorithms will become a hybrid optimization technique by combination of design, sustainable and supply chain in product development.

The developing of score metrics then will contribute on integrating the supply chain and the design stage of product development. As over 70% of the total lifecycle cost of a product is committed at the early design stage, designers are in a position to substantially reduce the lifecycle cost of the product they design, by giving due consideration to lifecycle cost implications of their design decisions (Asiedu and Gu, 1998). This score metrics develop next hopefully can be used by designer and engineer in early design stage to predict and evaluate the supply chain process so that the cost and time in the operational supply chain can be minimize by considering the aspects of sustainability.

CONCLUSIONS

This paper proposed the idea of development of score metrics for supply chain sustainability in the design stage. This new score metrics develops by making environment as main consideration. The objective of this research is to support the design stage where the supply chain sustainability can be predicted. As supply chain become successful method in manufacturing stage, authors tries to relate with two main issue involving design and supply chain sustainability in the link related information.

The framework of design phase in supply chain show the basic connection of prescriptive model adoptred from total design and supply chain activity. Through this framework, the area covered is limited on the supplier, producer and vendor (retailer and distributor) which directly involve in operational.

This research will use five tools including Design for X (DfX), Lifecycle Analysis (LCA), Quality Function Deployment (QFD), Material Degradation and Bullwhip Effect. This research finally will be develops a new information link for sustainability started from product brainstorming until customer base on product lifecycle management (PLM).

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