The Mediating Effects of Green Product Design on Economic Performance of Reverse Logistics: A Conceptual Study

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The Asian Conference on Society, Education and Technology 2014
Official Conference Proceedings

Abstract
The dwindling of natural resources and higher demand for landfill space fuelled the concept of sustainable consumption. For decades, buy and throwaway society created a string of negative environmental consequences and a positive change is taking place as developed nations take the lead in closing the supply chain loop via extended producer responsibility (EPR). Returns with higher residual value deserve attention because extending the useful life of equipment which underperformed earlier than expected generates an array of business benefits. The viability of reverse logistics activities depended on the effectiveness of reclaiming valuable constituents for reuse in as-new or used equipments. Drawing on the interests of sustainable development, this study investigates the mediating effect of green product design on the economic performance of reverse logistics among electrical and electronic (E&E) manufacturing firms in Malaysia. While ecodesign and reverse logistics were analyzed as components of green supply chain management in previous studies, this study intend to affirm the role of green product design particularly design for disassembly (DfD) and design for the environment (DfE) on the economic performance of reverse logistics. Since the characteristics of product design exert profound impact on waste minimization and elimination, this conceptual paper present a series of propositions to guide future empirical investigations in examining the relationships between reverse logistics and green design aspects on economic performance.

Keywords: Green product design; Reverse logistics; E&E; Malaysia; Design for disassembly; Design for the environment

1.0 Introduction

In view of environmental degradation, various stakeholders are becoming involved in shifting the throwaway society towards sustainable living. 3R program are among the initiatives that elevate the wellbeing of surrounding community and environment through reduce, reuse and recycling activities. Judging on rapid technological obsolescence and growth of secondary market for second hand goods, the local E&E manufacturing industry should commit resources in environmental proactive initiatives to deter negative environmental impacts effectively such as extending product lifecycle through the implementation of reverse logistics activities. Some manufacturers have invested in sustainable products and generated benefits from the green market industry such as reducing consumption of resources and reducing environmental impact during production, usage and post-usage phases (Mollenkopf & Closs, 2005; Rock & Angel, 2007). These environmental initiatives complement extended producer responsibilities (EPR) where producers are obliged to take financial and physical responsibility through take back programs to reduce the volume and toxicity of landfill waste (Lee and No, 2010; Terazono et al., 2007).

Since a legal framework to enforce EPR have yet to exist, Agamuthu and Dennis (2011) pointed out that most of the product recovery programs among Malaysian manufacturers are limited to voluntary participation. Only a handful of local companies accept used equipments from downstream customers as part of after sales services and it is unusual that firms collect them for proper recycling and disposal. It is only a matter of time that EPR is introduced to increase the traffic of returns and improve the efficiency of reverse logistics via bulk reprocessing. As reusability of products discourages viability of product recovery, Amelia et al. (2009) and Go et al. (2010) emphasized the importance of design for reuse to enhance reclamation of automotive parts. Similar conditions can be observed in the E&E manufacturing environment and more attention must be invested in reverse logistics particularly promotion of product redesign that accounted for barriers that deter recyclability. Even though a number of studies analyzed the components of green supply chain management (GSCM) such as green purchasing, green product design, green manufacturing, green distribution and reverse logistics (Zhu, Sarkis & Lai, 2007; Eltayeb, Zailani & Ramayah, 2011; Khor & Udin, 2013), all of them focused on performance outcome of GSCM. In contrast, this study looks into the role of green designing on the economic performance of reverse logistics.

2.0 Literature Review

2.1 Reverse logistics

Prahinski and Kocabasoglu (2006) defined reverse supply chain management as '*effective and efficient management of the series of activities required to retrieve a product from a customer and either dispose of it or recover value'*. There are five major processes to reverse supply chain management and they are product acquisition, reverse logistics, inspection and disposition, remanufacturing, and distribution and sales. Instead of exemplifying reverse logistics as transportation, warehousing, distribution and inventory management activities, this study treats reverse logistics as equivalent to asset recovery, where as-new or used products re-enter various marketing channels to extend the lifecycle of electrical and electronic equipments

(EEEs). This study defines reverse logistics as '*disposition options which are industry and product-specific, where decision-making highly depends on conservable value in used products. Products are reincarnated for efficient consumption and disposal of resources by recovering materials and energy invested within products, modules or components to reuse in forward supply chain to gain environmental and business benefits.*'

With comparison to practices in developed countries, the local manufacturing environment is not familiar with accepting and processing returns beyond warranty terms. Although the Minister of Housing and Local Government are authorised to enforce Clause 101 and Clause 102 of Solid Waste and Public Cleansing Management Bill 2007, which provide for (1) reduction, reuse and recycling of controlled solid waste, and (2) take back system and deposit refund system, the lack of framework for enforcement only managed to induce voluntary product take back programs. Despite the existence of such regulations, the absence of legislative enforcement system failed to regulate product recovery activities. This does not mean that reverse logistics activities are non-existence but rather, spare parts are in demand among third party remanufacturers or second hand repair workshops. In the case of Malaysia, Tengku (2011) pointed out that unlicensed or illegal operator conducted unregulated backyard dismantling and recycling activities in unsafe manners and inherently expose surrounding environment to the threats of harmful substances. With respect to Basel Convention on the Control of Transboundary Movement of Hazardous Wastes and Their Disposal, the Department of Environment (DoE) Malaysia introduced the 'Guideline for the Classification of Used Electrical and Electronic Equipment' to deter the exportation of e-waste that disguised as second hand goods. Since these restrictions preserve supplies at local waste streams and led to abundance of retrievable precious metals within end-of-use or end-of-life products, Malaysian manufacturers ought to weigh the benefits of EPR to take advantage of economies of scale recovery. Considering shorter technological clockspeed and higher rate of product obsolescence, the availability of valuable and functional assets is capable of reducing material costs especially for reconditioned and remanufactured EEEs.

2.2 Green Product Design

Based on Directive 2002/96/EC on waste electrical and electronic equipment (WEEE), producers are required to augment the rate of reuse and recycling of components, materials and substances up to the range of 50 to 75 percent of average weight per appliance for various categories of WEEEs. In line with this target, the Directive recommended that appropriate measures are taken during design and production of EEEs to facilitate dismantling and recovery unless the specific design features served as safety measures or meant to contain the effects of pollution. In other words, the recoverability of products is dependent on the readiness of the product to be recovered. Coined from the concept of product stewardship, the design team is obliged to incorporate green design aspects into products during the stage of product development to effectively alter the patterns of production and consumption.

According to Khor (2013), green product design ought to be employed as a corporate proactive approach that integrates product design and environmental considerations without compromising product's function and quality, including innovations for recovering product value throughout its life cycle prior to disposal. Of late, a number of producers have joined the bandwagon of greening by adopting less complex approaches such as reduction of material and/or energy consumption. However, more efforts must be invested on design for disassembly, reuse and recycling to mobilize green economy and achieve greater green leaps. Since most the hard value of asset recovery is extracted during disassembly process, this study looks into the utilization of modular subassemblies, accessibility of valuable components or parts, and separability of joining elements. For instance, producers can implement minor design changes that put forth immense benefits to facilitate value recovery such as minimize the quantity of fastening elements, use of snap fits in lieu of screws, and avoid the use welds or adhesives (Desai & Mital, 2003; Mathieux, Froelich & Moszkowicz, 2008; Tien, Chung & Tsai, 2002; Veerakamolmal, 1999). While disassemblability of products accommodates the reuse of parts or components, the recyclability of product only yields recyclable materials. Unless there are economies of scale in product recycling, the cost of harvesting recycled material is unattractive to businesses. Generally, most firms have established procedure for recycling scheduled waste to comply with environmental management standards. Since in-house recycling and bulk recovery are rare instances, designing for recycling is not a pressing issue as compared to design for disassembly and design for the environment, where both directly affect the intricacy of product inspection and high value recovery.

2.3 The Direct Effects of Green Product Design and Reverse Logistics on Economic Performance

While the value of returns in the U.S. market may exceed $100 billion dollars per year (Stock & Mulki, 2009), the existence of product take back and recovery activities is only a fraction of total sales among firms in developing nations particularly Asian countries. Generally, Guide et al. (2000) indicated that uncertainty of timing, quantity and quality of returned products complicates the management of inventories. On top of it, the lack of market for recycled materials indicates the lack of financial prospects, thus impeding producers' interest in reprocessing end-of-use and end-of-life equipment. In contrast, firms can develop an array of secondary market to liquidate reusable or preowned equipments and recover the transportation and handling cost for extending products' lifecycle. These options include, but not limited to online auction site, factory outlets, value retailers, pawn shops, dollar stores, flea markets and charities (Rogers, Rogers, and Lembke, 2010). The availability of secondary market is a viable reason for generating positive environmental and economic outcome from the sales of excess inventories or materials via investment recovery (Zhu and Sarkis, 2007).

Although extending product lifecycle could be a viable business, the asset recovery operations face immense challenges in extracting subassemblies and components that are of good and functional condition. The complexities involved in reprocessing are unappealing to businesses due to the cost of asset recovery. Considering that most products are not designed for easy disassembly, the economic viability of reverse logistics product disposition is challenged by high cost in hiring skilled labor to dismantle EEEs (Kumar & Putnam, 2008). Unlike forward manufacturing assembly where driving down production cost per unit is one of the business goals, the backward supply chain incur substantial resources to extract valuable components and manufacture used products for secondary markets. Although one can argue that the profit margin of asset recovery is much lesser due to handling and transportation costs, the cost reduction opportunities from reusing materials particularly whole products or functional subassemblies justify the viability for engaging greener businesses. Additionally, Ayres et al. (1997) presented evidences on the profitability of reverse logistics i.e. dismantle to retrieve good parts and active recycling at IBM SEMEA, manufacture as-new products at Rank Xerox, recycle integrated circuits to serve niche market at Aurora Electronics, and more. Other manufacturing companies rode on proper recycling and disposal of end-users' EEEs as social responsibility initiatives to serve a growing consumer base who are receptive towards environmentally friendly activities.

Reverse logistics activities are being implemented out of concern for the environment. However, Skinner, Bryant and Richey (2008) revealed that reverse logistics disposition strategies do not result in superior economic performance. Nonetheless, Khor and Udin (2012) showed that some disposition options specifically repair, remanufacture and recycle and disposal associate with economic outcome but none indicated improvement in environmental performance. For that reason, this study acknowledges that economic performance is important and focused on profitability and sales growth as measures of reverse logistics. On the other hand, the performance of green product design, also known as ecodesign, consistently generate positive effects because minor changes including favourable choice of materials and minimization or substitution of hazardous substances are 'low-hanging fruits' that allow firms to look good among eco-conscious customers. Since a wide selection of studies conducted in various industry settings substantiated the economic performance of ecodesign, this study takes a slightly different direction and emulates Khor and Udin (2013) in analyzing design for disassembly and design for the environment as components of green product design. Based on previous literatures, this study proposed that:

P1: Reverse logistics has a significant relationship with economic performance.
P2: Green product design has a significant relationship with economic performance.

2.4 The Mediating Effects of Green Product Design

A number of studies have empirically examined the performance of green supply chain management (Eltayeb et al., 2011; Khor and Udin, 2013; Ninlawan et al., 2010; Sroufe, 2003; Zhu & Sarkis, 2007) but none investigated the indirect effects of green product design on the performance of reverse logistics. While the value of recoverable assets determines the success of reverse logistics, the recoverability of assets depended on the product characteristics that support material recovery. Recall that green products are conceptualised to reduce the demand for material and energy. The asset recovery operations ought to communicate the challenges that deter effective retrieval so that designers can take relevant measures during the conceptualization of new equipments. Therefore, the greenness of products is determined by how demand for natural resources declines due to efficient use of nonrenewable resources. Some green products had been successful in reducing the demand for energy but many failed to fulfil the objectives of sustainable development because most of the materials were not recyclable or recycled through proper channels. Based on Krikke et al. (1998), the extent of disassembly required by product repair, recondition, remanufacture and recycling activities increases across respective levels specifically product, module, part and material level. Although various studies examined green product design as design that reduce or eliminate the use of hazardous substance, this study attempt to emphasize the importance of designing for disassembly to facilitate extraction of reusable constituents because the value of recyclable material is relatively minuscule.

Various issues that hinder parts recovery or materials recycling are communicated to design personnel so as to redesign the structure and composition of equipments (Ayres et al., 1997; Talbot, Lefebvre and Lefebvre, 2007; van Hoek, 1999). The interdependence between green product design and reverse logistics product disposition determines the success of product take back and recovery programs. For instance, Ferrer (2001) enlisted bonding, joint-stamping, riveting and welding as fastenings that aid effective product assembly but these joints were almost impossible to disengage without damaging (e.g. cosmetic damages) at least one of the conjoined parts and/or components. As choices of joints disrupt effective reuse of recoverable value, the asset recovery operations generates poor recovery rate, missed cost reduction opportunities and high demand for specialized personnel. These instances become feedback to designers' learning curve and rationalized the integration of green design aspects when developing future products. Note that collaboration between personnel from asset recovery and design departments is important to iron out various complexities encountered during the process of recovery and recycling. For instance, some recommendations include us of breakable snap fits in lieu of screws if they do not impact the structural strength of products, use environmentally preferred materials to ease the handling of hazardous materials, and response to designers on frequency of malfunctions that occur prior to their expected lifespan.

Since previous researches provide solid empirical grounding on effects of reverse logistics and green product design, the current study intend to examine the mediating effects of green product design based on the following propositions:

P3: Reverse logistics has a significant relationship with green product design.
P3a: Reverse logistics has a significant relationship with design for disassembly.
P3b: Reverse logistics has a significant relationship with design for the environment.
P4: Green product design mediates the relationship between reverse logistics and economic performance.
P4a: Design for disassembly mediates the relationship between reverse logistics and economic performance.
P4b: Design for the environment mediates the relationship between reverse logistics and economic performance.

3.0 Theoretical Framework and Instrument Development

The current model is synthesized from the empirical studies conducted by Zhu et al. (2007), Eltayeb et al. (2011), Sroufe (2003), Skinner et al. (2008) and Talbot et al. (2007). Based on previous literatures, Figure 1 depicts the theoretical framework of this study where green product design specifically design for disassembly and design for the environment exert indirect effects on the relationship between reverse logistics and economic performance. The examination of recoverable products for closing the supply chain loop begins with product disassembly. As time-sensitive approach is required to manage the value of reusable equipment, disassemblability takes precedence over recoverability since the inspection and testing phase starts off with accessibility and separability of high-value parts.

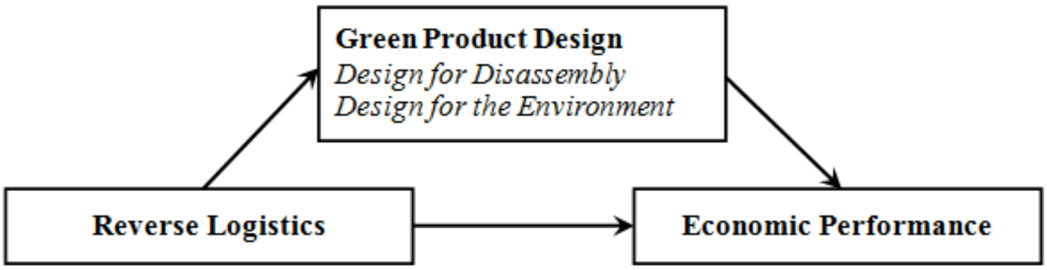

Figure 1: Theoretical Framework

With reference to Table 1, the measurement items for reverse logistics, green product design and economic performance of reverse logistics are adapted from literatures across the field of reverse supply chain management, green supply chain management and environmental management. Respondents are required to evaluate the extent of existence of green supply chain practices and level of significant economic performance based on five-point Likert type scale. Recall that the extended producer responsibility policy will be eventually introduced to induce environmental commitment among E&E manufacturing firms because the global environment including Europe, United States, Japan, Korea, Taiwan and China have introduced legislations to govern WEEEs. In staying ahead of the competition, product designers are encouraged to adopt forward thinking to build green reputation among environmentally conscious customers and reduce the cost burden associated with product take back and recovery programs.

Table 1

Variables and Measurement Items

Variables	Sources
Reverse Logistics	
1. Repair is the correction of faults in a product. 2. Recondition replaces all major components that have failed or that are on the point of failure. 3. Remanufacture is the work for returning product to at least OEM original performance specification. 4. Recycle involves reusing materials from used products and components.	Ijomah et al. (2007) King et el. (2006) Krikke et al. (1998) Skinner et al. (2008) Thierry et al. (1995)
Green product design	
Design for Disassembly 1. Design products that use modular components. 2. Design products that use snap fits in lieu of screws. 3. Design products that minimize the number of fasteners. 4. Design products that ease accessibility of valuable components/materials.	Bogue (2007) Cerdan et al. (2009) Dowie (1994) Kriwet et al.(1995)

5. Design products that ease accessibility of joining elements. 6. Design products that consider the weight, shape and size of structure for disassembly.	
Design for the Environment 1. Use pollution-free raw materials in production. 2. Use raw materials that are compliant with environmental protection regulations. 3. Design of products that reduce consumption of materials. 4. Design of products to avoid or substitute the use of hazardous substances.	Eltayeb et al. (2011) González-Benito & González-Benito (2005) Tien et al. (2002) Zhu et al. 2007)
Economic Performance	
1. Significant improvement in revenue from after sale services. 2. Significant reduction in cost of goods sold for recovered products. 3. Significant reduction in the cost for purchasing raw materials, components or subassemblies. 4. Significant improvement in market share. 5. Significant improvement in corporate environmental reputation among environmentally conscious customers. 6. Significant improvement in sales growth.	Daugherty et al. (2001) Eltayeb & Zailani (2011) Klassen & McLaughlin (1996) Rao (2002) Talbot et al. (2008) Montabon et al. (2000) Zhu et al. (2007)

4.0 Conclusion

This conceptual paper wishes to highlight the importance of green product design in reducing the volume of landfill wastes. Although negative environmental consequences have caught the attention of various external stakeholders, producers seemed to exert lack of enthusiasm towards product take back and recovery programs because the complexities encountered during the stage of product reprocessing overwhelm profit generating opportunities. There is substantial value in extending the lifecycle of end-of-use and end-of-life equipments because many retire prior to their expected lifespan due to failure of few critical parts. Nevertheless, some forward-thinking manufacturers obliged by the concept of product stewardship to compete including rethinking environmental impact of product lifecycle via redesigning for reuse. The framework of this paper recognised the economic benefits of reverse logistics and acknowledged that it is best that the product development team address some barriers that deter the business viability of equipment recovery. Future research should gather empirical evidences to determine the effectiveness of simultaneous reverse logistics and green product designing implementation. The prospects of dual initiatives in securing monetary value while reducing negative environmental impacts ought to entice producers to adopt environmentally responsible businesses.

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