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Performance measurement of product returns with recovery for sustainable manufacturing

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ABSTRACT

Today's lifecycle of new and emerging products, increase in labour costs in developed countries and user's expectations or behaviours including frequently upgrading items with latest features, influence the growth rate of product disposal to landfill. To reduce the negative impact on the environment, global manufacturers need to take responsibility for designing sustainable products and implementing cleaner production systems for 3R operations (3*R–Reuse*/*Remanufacture*/*Recycle*). Nevertheless, there is still a lack of comprehensive measures for assessing product returns with recovery settings. In this paper, a framework for performance evaluation using design for six sigma methodology is developed to estimate utilisation value of a manufactured product with recovery settings, which accounts for total recovery cost, manufacturing lead-time, minimisation for landfill waste and quality characteristic. Finally, a numerical example based on these performance attributes to assess product utilisation value is presented.

1. Introduction

Due to rapid changes in advanced technology development and a need for the introduction of new innovative products in the markets, research on product returns with recovery options has emerged as an important research area [1–3]. Environmental directives such as WEEE (waste electrical, electronic and equipment), RoHS (restriction of hazardous substances), ELVs (end-of-life vehicles) and EuP (energy-using product), ISO 24700:2005 standard and guideline have been proposed for controlling environmental impacts associated with manufacturing processes [4–6]. These proactive initiatives also stipulate original equipment manufacturers (OEMs) to account for the environmental degradation of landfill due to the product disposal and to consider product returns with recovery operations.

In recent years, returns management process has been recognised as one of the key supply chain management processes by Supply Chain Operations Reference (SCOR) model and the Global Supply Chain Forum (GSCF) framework for promoting environmental conscious manufacturing [7–9]. Nevertheless, the quantitative performance evaluation and analysis of the returns management process still remains a challenge due to the limitation of performance assessment guidelines, which can address the complexity of recovery operations and collection related activities [4,10]. Subsequently, the involvement of various multiple suppliers, manufacturers, retailers, consumers and collection agents within supply chain networks is a another crucial bottleneck in designing optimised product returns workflow with recovery settings [11]. Therefore, performance evaluation with returns workflow for manufacturers should include selection of the appropriate measures and methods for interpreting outcomes of recovery operations and improvement analysis.

Guide et al. [12] highlighted seven primary characteristics of uncertainties within product recovery activities such as uncertainty of timing and quality returns, the need to balance returns and demand management, disassemblability of returned items, complications of mix-material matching restrictions and stochastic routings for material flow and uncertainty of processing times. To account for all the risks of uncertainties, which are related to recoverable items, a proposal for the trade-off method to assess performance measurement is used to examine the utilisation value of recoverable content for a manufactured product. The purpose of this method, which is based on this trade-off scenario, aims to satisfy environmentally conscious practices associated with economic benefits for a manufactured product with recovery settings and to meet the requirements of a primary or secondary market, which remains unexplored and limited [7]. In general, this paper is concerned with the implementation of the performance assessment for recovery operations as a strategic enabler towards

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sustainable manufacturing. An attempt is also made to examine the performance attributes of cost, time, waste and quality of a manufactured product with recovery settings.

2. Literature review

There are concerns about social responsibility and extended producer responsibility (EPR) for waste minimisation management strategy when considering sustainable development [13,14]. Further, waste disposal costs and operating costs associated with virgin materials usage are steadily increasing [15]. Therefore, a need for minimising disposal of used products to landfill has arisen [3,16,17].

In comparison with conventional manufacturing, any alternative for reclaiming resources helps on reduction of energy consumption, material extractions and landfill of the used product [3,18]. Hence, the performance assessment for returns management process needs to include aspects such as financial or rebate incentives by manufacturers [3,19], reverse logistics and administration of returned items [13,15,20] as well as the operational processes for sub-assembly or disassembly [21], recovery processes [22–24], and disposal of hazardous or non-hazardous items [3,7]. As a result of these critical aspects, a trade-off method may be a preferable option for assessing product returns with recovery settings [7,11,25].

Using trade-off considerations, a conventional 6R interpretation (*reduce/reuse/recycle/recover/remanufacture/redesign*), was initially proposed by a few researchers [23,26,27] for an agenda of sustainable manufacturing. Kuik et al. [7,11] classified waste minimisation along a supply chain to account for any complexity of the product returns workflow with recovery settings by proposing a strategy of 3R process improvement (*reuse/remanufacture/recycle*) level and 3R product design (i.e. *reduce/recover/redesign*) level towards sustainable development milestone as illustrated in Fig. 1. The product utilisation value (PUV) of a manufactured product, which is indicated by a solid trend line (see Fig. 1) is defined as the expected amount of the recoverable content for a manufactured product with 3R process improvement strategy. A few manufacturers are implementing recovery operations, including Caterpillar, Kodak, Mercedes-Benz engine components, IBM computers or Xerox electronics [3]. In comparison, the dotted trend line in Fig. 1 indicates expected amount of recoverable content for a manufactured product using an integrated approach by incorporating both 3R process improvement and 3R product design strategies. This approach is generally known as the design for product retirement (DFPR) and product end-of-life (EOL) planning [28,29], which is an alternative way of achieving maximum PUV with recovery settings to satisfy the stringent requirements of product disposal to landfill.

The estimated PUV from this integrated approach is recommended to incorporate a strategy of 3R process improvement concurrently with the design constraints of 3R product design strategy for maximising the value [7,8]. The proposal for this approach also comprises modularisation of product design, the consideration of design for assembly or disassembly, the limitation of hazardous coating materials and the utilisation of more remanufactured or reused components. To differentiate the definition of 3R process improvement and 3R product design strategies, minimisation of waste landfill by means of 3R process improvement and 3R product design strategies have been summarised by researchers [7,8,11]. At *'post-use'* stage, the performance measurement method for this scenario is still at a budding level, especially, for a manufactured product with recovery settings. This integrated approach will assist global manufacturers evaluate a trade-off scenario by considering the perspectives of total recovery cost, recovery manufacturing lead-time, minimisation for landfill and quality characteristics [11,30].

3. Product recovery for sustainable manufacturing

Product disposal to landfill is one of the major problems [30]. A 6R approach, which considers recoverable components for a manufactured product, provides a better opportunity for reducing resource consumptions, raw material extractions, and manufacturing lead-time. Kumar and Malegeant [31] discussed two prime constraints of closed loop supply chain management, such as no

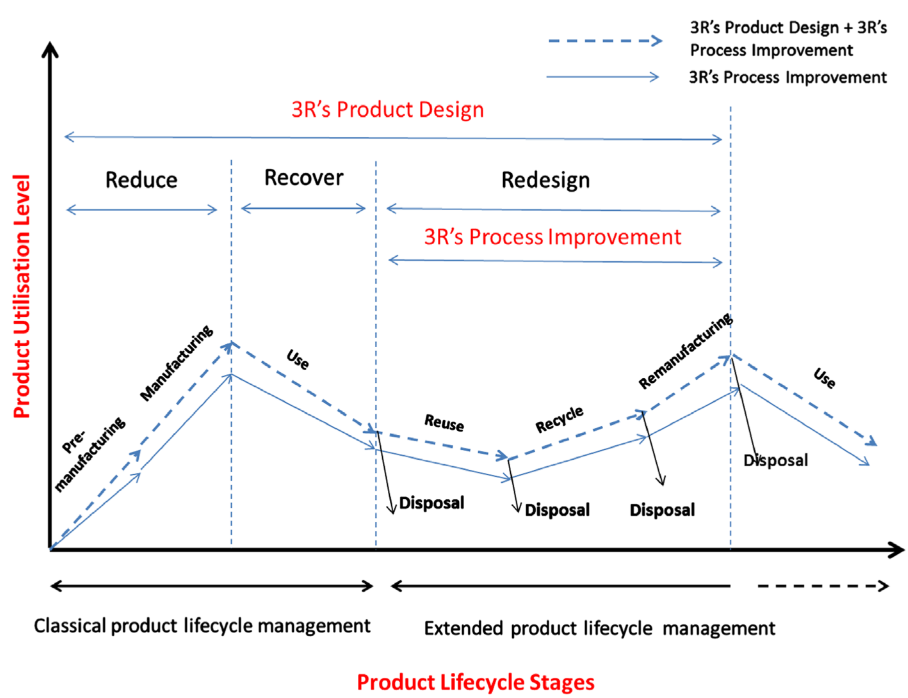

Fig. 1. Product utilisation value by implementing 6R approach.