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Maximising the retained value of product cannibalisation based on circular economy principles

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Abstract

The maximisation of retained value is one of the determinants in the circular economy that can prolong the product economical and functional values. This paper aims to maximise the retained values of cannibalised products based on the circular economy principles. The approach mainly has been through the desk-based research. The steps to maximise the retained value are developed by adhering to the rules of product cannibalisation and by calculating the retained values. The identification of circular economy principles that is applicable to reverse logistics, particularly product cannibalisation that can contribute to the maximisation retained value process.

Keywords: Reverse logistics, Product cannibalisation, Circular economy principles

Introduction

The idea behind circular economy (CE) has already been stated by some researchers such as Boulding (1966), Kneese et al. (1970), and Pearce and Turner (1990). CE concept was not only discovered by single researcher, it is also supported by other researchers that focused on other concepts, such as regenerative design, cradle to cradle, etc. EMF (2013) defined CE as a global economic model to minimise the consumption of finite resources that focus on intelligent design of materials, product, and systems. It also describes to separate treatment between technical and biological materials in the maximising design for reuse through innovations across fields (Webster, 2015; Lacy and Rutqvist, 2015).

To implement CE in the real system needs to understand the concept comprehensively, through CE principles; the understanding and implementation process of the concept might be simpler. The principles will represent the important values of CE concept. By identifying the CE principles the concept will be represented, therefore the formulation of the CE principles are required. The readily available format or structure of principles will support the understanding and implementing process.

Some researchers described the CE principle for instance Huamao and Fengqi (2007); Stahel (2013) in Ellen MacArthur Foundation (2013); EMF (2013) explicitly. Others authors were describing implicitly such as Yuan et al. (2006); Preston (2012) through the activities of CE. Those researchers have not explained the step by step method to formulate the principles. Also the principles were not described in the available format that can be used in the specific cases in order to product reverse logistics, specifically product cannibalisation.

Cannibalisation is explained as a taking selective retrieval parts in the process of restoring a product that can prolong the lifetime of product. Thierry et al. (1995) were explaining the process of product cannibalisation where they indicated as a simple process which less than 10% can be cannibalised in used product. This research will implement the maximising retained value as one of determinant to product cannibalisation. The implementation engages some rules and processes that will prove that by adopting CE principle, the retained value will increase functionally and economically.

This research aims to maximise the retained value of reused parts and cannibalised product based CE principles. The details process will be illustrated in mathematical formulation that it can compare before after adopting CE principle in the product cannibalisation.

Literature Review

Product Cannibalisation

Term of cannibalisation is defined some dictionaries that is related to an attempt for restoring a function of product or machine that can be taken a part of similar or another product. Cannibalisation was defined some researchers such as Copulsky (1976) in Guide and Li (2010) as “the extent to which one product’s customers are gained at the expense of customers of other products offered by the same firm”; Heskett’s (1976) in Lomax et al. (1996) as “the process by which a new product gains sales by diverting them from an existing product”. Cravens et al. (2002) also illustrated a framework for a proactive cannibalisation that responds to changing customer value in the process of building appropriate innovation strategies for the new competitive and technological environment. Those cannibalisations researches above are using in the marketing context. On the other hand, cannibalisation in reverse flow in order to product recovery context was discussed by Thierry et al. (1995). They described that level of disassembly, quality requirement, and resulting of the product is respectively to select retrieval of parts; depends on the process will be reused; some parts reused, and the remaining product will be recycled and disposed. They also described that product cannibalisation contributes to minimise the new spare part that can affect against number of reduction non-reusable waste.

Circular Economy Principles

The principles of CE are formulated to support the understanding of the concept. A ‘principle’ is generally intended as a fundamental truth that serves as the foundation of a system. The CE principles can therefore be seen as the fundamental truth of circular economy. CE principles have been identified by researchers in different contexts. Huamao and Fengqi (2007) and Yuan et al. (2006) summarised the CE principles in “3R” which stands for *reduction*, *reuse* and *recycling* of materials/energy. Hu et al. (2011) expressed the basic philosophy of CE that enhances the emergence of an industrial and economic system, relies on cooperation among actors and matter, and uses waste material and energy as resources to minimise the system’s virgin material and energy input. Stahel (2013) in Ellen MacArthur Foundation (2013) emphasised the importance of CE

principles in the implementation of CE concept. He explained CE principles including economics and profit maximisation; material and resource sufficiency and efficiency; an intelligent use of human labour; caring. Additionally, he defined ruling of CE principles: profitable and resource efficient; value maintained; circular flow; cost efficient: reuse, repair and remanufacture; needs functioning markets. Those of principles have been expressed, are not described as available guide than can be implemented in a specific case easily.

In addition, Some principles of CE have been identified by EMF (2013) which includes: 1) *design out waste*, meaning that when a product is designed, the designer needs to consider the biological or technical material cycle that can be reprocessed; 2) *build resilience through diversity*, meaning that there is a need to build a system resilience covering several aspects within CE; 3) *work towards using energy from renewable sources*, meaning that energy usage per unit of output needs to be reduced and the shift to renewable energy needs to be accelerated by design, treating in the economy as a valuable resource; 4) *think in system*, meaning that a set of components or objects that interacts each other to achieve the goals in real-world, non-linear, feedback-rich systems, particularly living systems; and 5) *think in cascades*, meaning that maximisation the retaining value of product that can contribute optimally before going back to biosphere or continuing loops.

Those of principles have been expressed, are not described as a readily available format that can be followed to be implemented in a specific case in order to reverse logistics operations, specifically product cannibalisation.

Methodology

The approach of this paper mainly is the desk-based research where the data were collected from publication databases and other scientific resources by using a wide range of keywords and the associated phrases. These were combined with the publicly available materials and various sources related to circular economy, reverse logistics, and product cannibalisation.

In order to formulate CE principles, the search process was started by selecting the publication databases including journals, books, technical reports, conference publication, white papers, articles, and videos. There are five steps in the formulation process of CE principles: literature filtering, literature analysis, thematic analysis, definition of CE values, and mapping of CE values. The numbers of papers have been found: Google Scholar = 519 articles, IEEE Xplore = 6 journal articles and 196 conference publications, Scopus = 118 articles and Electronic Journal Service (EBSCO) = 433 publications.

In the *literature filtering*, all of sources were filtered by analysing the title, keywords, key ideas, abstract, and graphics. Through this process, there were 30 scientific sources discovered. Next process is *literature analysis*, the 30 scientific sources were analysed deeper to construct some themes that will be projected become some CE principles. Those sources produced some themes based on intersection of the definition, characteristics, principles, etc. (e.g. Pearce and Turner, 1990; EMF, 2013; Lacy and Rutqvist, 2015). *Thematic analysis* was done to produce the CE principles. The fourth process is *defining the CE principles* that have been found, this step intended to provide the clear information of the principles. And the last step is *CE principles mapping*, this step is to affirm whether each principle has the similar level of degree or there is another level. By implementing those steps that have been discovered some principles.

Furthermore, the implementation process of the principles is implementing the principles into specific case. This process also was done based on the literature review by using some cases where the detail activities will be explaining further.

Results

Circular Economy principles

The CE principles are found based on five steps: literature filtering, literature analysis, thematic analysis, CE values definition, and CE values mapping. Through those steps, some principles have been produced, such as maximising retained value, optimising the economy, and eliminating waste (Ripanti et al., 2015).

Maximising retained value can be defined as creating a system that can keep/maintain a product with maximum value within the longer duration of life a product. It is also described that a product basically faces a shrinking value time by time that will make its value declined. However, through a suitable treatment, these situations can be avoided. The end of life product utilising can through reusability activity. A comprehensive business model is needed which it should consider a profitability, environment, economy, collaboration, etc. This value will provide technical protocol to maximise retained value of the product (Pearce and Turner, 1990; Hu et al., 2011; EMF, 2013).

Eliminating the waste, this value must be applied from flow of origin which is raw material until customer, and also from customer to raw material. The elimination of waste can be started from designing product that support, the possible number of waste such as the material, design, etc. Or the process from customer to be raw material will provide a system that can eliminate number of waste (e.g. Pearce and Turner, 1990; Hu et al., 2011; Zheng and Zheng, 2013, EMF, 2013).

Optimising the economy, this principle emphasises on the achievement of production and consumption, service and supply of money that the resilient economy can create, for instance, improving material productivity, enhancing innovation capabilities, and shifting from mass production employment to skilled labour. The optimisation practically cannot be done without considering the environmental aspects such as material and energy input, amount of carbon emission, balance of trade, cost saving, etc. (e.g. Boulding, 1966; Pearce and Turner, 1990; Kneese et al., 1970 in Anderson 2007).

In the process of implementation, this paper only focused on one principle which is maximising retained value. It implemented in the product cannibalisation.

Product Cannibalisation

The details of the process are needed to be illustrated to describe the product cannibalisation in the context of RL activities. In this research the process was identified based on literature review by some researchers such as Thierry et al. (1995), Fleischmann et al. (2000), and Kim et al. (2006). They figured the RL process in different activities: product recovery management, recovery chain, and remanufacturing respectively. Each author provided an illustration that depicted the flow process of each activity. Each activity also has relation that can be concluded that the general activities in the RL are similar, but indeed it depends on which activity that will be concerned on. Product cannibalisation here is described as a part of RL. Literally, the involving main activities will be similar with the general process of RL, where the process is returning product from where it is used to its origin. However, the difference is specific treatment inside of each recovery options, in this case is product cannibalisation. The product cannibalisation flow needs to be illustrated, where generally it is depicted in Figure 1. The process can

be started from customer returns the used product to the collection centre. It is transported to the disassembly centre for assessing the quality of the product. In the cannibalisation centre, the process of recovering a limited of parts from the used product/component that has been collected. The next process is transporting the cannibalised product to the other entities, such as secondary market, or manufacturer; there are also inventory, recycling centre, and disposal centre. Those centres are providing to cover any other possibilities, such as in the process of cannibalisation, could produce some recycled or waste products, or due to some reasons, the product needs to store. Fundamentally, the name of the centre can be different; the most important is covering the function of the entities.

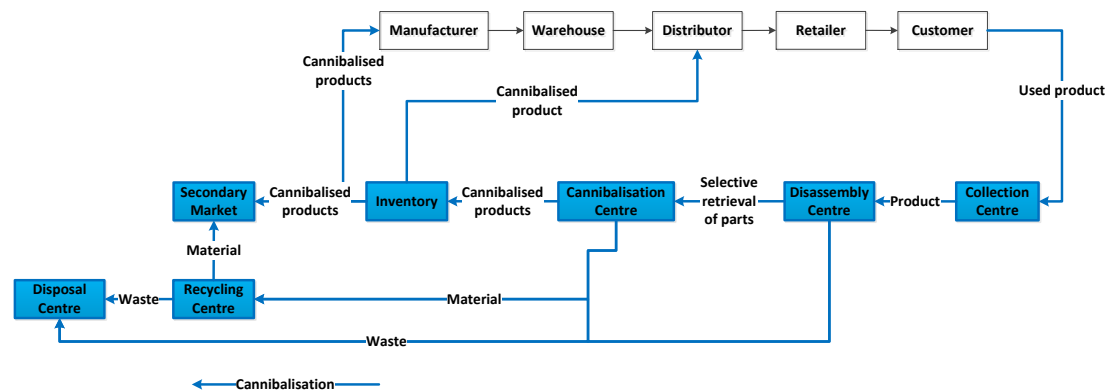


Figure 1 - Cannibalisation activities

The operation of cannibalisation was affirmed by Thierry et al., 1995 as a simple process where it covers some process: certain disassembly of used product, retrieval potential useful parts, and testing the retrieved parts.

Embedding CE Principles into Product Cannibalisation

The purpose of embedding CE principles (maximising retained values) to product cannibalisation is to increase the maximisation of retained values functionally and economically that can keep longer product in the circulation, reduce the level of obsolescence. There are some steps to embed the process of maximising retained value in to product cannibalisation. Here, we already had one CE principle that will be implemented. The case that has been chosen is a product cannibalisation. Consequently, there are some detail rules and processes technically to fulfil the purposes. The detail rules are formulated to prove by implementing CE principles to product cannibalisation that the purposes are achieved. The rules are: **(1)** the maximum number of reused parts and **(2)** the maximum number cannibalized product. *The first* rule has some processes: pre-assessing, disassembling, testing, and classifying reused parts. *The second* rule has some processes: assembling, testing, and calculating.

In this research, a case is represented to describe the implementation obviously. A personal computer (PC) was taken as an example of one product type. Firstly, the number of parts of PC needs to be identified. For example, a PC consists of eleven (11) parts. By identifying the same unit of product (e.g. part/material/product), it will be possible to optimise the number of retained value whether to cannibalise, recycle, or dispose. Identifying the number of parts will be a standard to calculate the retained value of product. For example, a collection point collected 100 PCs with diverse qualities. The level of the quality of PCs needs to be assessed. The next is assembling process of some parts and classifying the parts in the same part and quality. The last process is calculating

the parts that have been classified. After knowing the number of possible parts to be cannibalised, the parts need to be assembled become a new cannibalised PC, after that the PC needs to be tested to ensure that the quality has fulfilled the cannibalised product standards.

Moreover, the detail process describes both rules that are needed. To maximise the value of retained product that can be increased, calculating process in the *second rule* has one rule base (see Rule-Base 1); where, it defines that the product/part can be assembled, if it meets the condition. In the assembling process, the reusable product will be collected in the same classification, here also there is possibility to repair several parts that the number of reusable part can be increased. The calculating process also will calculate the final result of retained value part/product functionally and economically where the percentage can be known by comparing previous value of retained product. The calculating process can be conducted by following some equations.

For example, there are three PCs have been collected (by collection centre) with different quality. Through the processes in the first rule: assessing, disassembling, and calculating the reused parts, the quality of parts of each PC can be categorised in to two; “**can be used**” and “**cannot be used**” parts that are indicated by 1 and 0 respectively (see Table 1). Table 1 is illustrating the result of assessing, disassembling and calculating of the reused parts of 11 collected PCs. **P1 – P11** indicate eleven parts of each PC, and **PC1 – PC3** indicate that there are three PCs have been collected in collection centre.

Table 1 – The result of assessing

	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	Total Part / PC
PC1	1	0	1	1	0	0	1	1	1	1	1	8
PC2	1	1	0	0	1	1	0	1	1	1	1	8
PC3	1	0	0	0	1	1	1	1	1	1	0	7
Total each part	3	1	1	1	2	2	2	3	3	3	2	

To fulfil **the first rule** which is calculating the maximum number of reused parts or maximum number of retained value in functional $max(funReVal)$, it can be considered in the equation (2). The number of reused part or $funReVal$ of collected product describes in the equation (1).

$$funReVal = \sum_{i=1}^m \left(\sum_{j=1}^n \frac{Part_j}{n \times m} \right)_i \quad (1)$$

Where:

m = number of collected product

n = number of part per product

The objective function:

$$max(funReVal) = max \left(\sum_{i=1}^m \left(\sum_{j=1}^n \frac{Part_j}{m \times n} \right)_i \right) \quad (2)$$

To maximise the number of cannibalised product needs to follow a condition that describes in the rule-base statement below:

```

Do
    Check  $p[i]$ 
    If  $(\forall p[i] \geq 1)$  then
         $nCanPro++$ 
    End if

    Next  $(p[i])$ 
Until  $p[i] = 0$ 

```

Rule-Base 1. Pseudocode for calculating the number of cannibalised product

The Rule-base 1 means that to cannibalise one product, all availability of used part of product should be *at least one*. If the condition $(\forall p[i] \geq 1)$ is fulfilled, the number of cannibalised product ($nCanPro$) increases. The counting process *will be terminated* when *one used part* is zero.

The Table 1 describes the number of reused parts for PC1, PC2, and PC 3 are respectively 8, 8, and 7. By using the equation (1), the retained value of product should be:

$$funReVal = \frac{23}{33} = 0.67$$

It means, for this case, the retained value of collected product (after process of assessing, disassembling, and calculating the reused parts) is 0.67. It can be assumed, that **0.67** (or 67%) is a “functionality retained value” ($funReVal$). If, for assumption, the functionality retained value of all collected products is zero, so there is 67% of product function can be retained.

Furthermore, based on Rule-base 1, the cannibalised product that can be produced is one cannibalised product (PC). The price of cannibalised product and the price of all other remaining used parts can be used as an “**economic retained value**”. For example, the justified price of cannibalised product is X, the justified price for all other remaining used spare parts is Y, and the assumption of market price of specific product is Z; the “economic retained value” can be calculated by using equation (3).

$$ecReVal = \frac{X + Y}{Z} \quad (3)$$

For example, the justified price of one PC is £100, the justified price of all remaining used parts is £100, and the market price of PC (with the same specification) is £600. So the $ecReVal$ for this case is **0.33** (or 33%). If, for the first time (when the collection centre collected the product) the retained value of all collected product (by considering the depreciation value) is only £60 (or 10%, for example), the process of cannibalisation has successfully **increase the economic retained value of the product 23%** (33% - 10%) approximately.

To find the total retained value of the product in functional and economic can be calculated by using equation (4). So, the total retained value of three collected PCs is 50 percent after facing maximising retained value processes.

$$totalReVal = \frac{funReVal + ecReVal}{2} \quad (4)$$

$$totalReVal = \frac{0.67 + 0.33}{2} = 0.5$$

The results above provide the opportunities to maximise retained value into product cannibalisation operation through some rules and processes.

Discussion

In the context of reverse logistics, product cannibalisation is relatively rare to be discussed academically. Some researchers previously discussed it, such as Copulsky (1976), Heskett's (1976), and Cravens et al. (2002). However, they focused on the marketing context. Thierry et al. (1995) is one of the researchers that explained the product cannibalisation as a part of specific product recovery activities. Nevertheless, those researchers are not describing product cannibalisation based on CE principles as this research focused on.

This research provides some rules that can potentially increase the maximum of retained value of the used product functionally and of product cannibalisation economically. However, the specific requirements that need to be followed (such as some rules and challenging processes) are several consequence of adopting of CE principles in the product cannibalisation process. The rules and processes might be not really simple, but it offers some advantages, such as the number increase of reused part and cannibalised product through the rigour assessing and testing. These processes also will keep the value of product longer in the circulation; eliminate the number of wastes, increase time delay of obsolescence of product; and increase number of the “new” spare part or product.

The uniqueness of this research is that in providing the rules, there is calculation process that can be an indicator whether the retained value functionally and economically increases or no. This process was not considered before CE principles were adopted.

Conclusion

The embedding CE principles specifically maximising retained values into RL activities in order to product cannibalisation have some general steps or rules that need to be followed. Each rule and process provided some mathematical formulations. The adoption of maximising retained value in product cannibalisation has positive impact to other CE principles, such as eliminating waste, conscious the environment, and optimising the economy. The rules of maximising retained value to product cannibalisation needs to be validated, this task can be continued for the further research.

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