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Collection-disassembly problem in reverse supply chain

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ABSTRACT

The reverse supply chain and disassembly processes are getting more and more important for tackling the burden of waste electrical and electronic equipment. The disassembly's complexity and frequent manual operation makes this process relatively expensive compared to its potential profit. The collection of end-of-life product is also a big issue dealing with vehicle routing. Thus, the decisions taken for collection and disassembly of end-of-life products need to be optimised. In this work, an optimisation model is developed for incorporating these problems. Our experimental study shows joint optimisation of collection and disassembly with coordination between them improves the global performance of the reverse supply chain including lower total cost corresponding to the component demand satisfaction.

1. Introduction

The annual amount of waste within EU territory is around 4 million tons including waste electrical and electronic equipment (WEEE) of which is prohibited by EU Council Regulation 2002/96/EC on WEEE. This directive stipulates that WEEE is "one of target areas to be regulated, in view of prevention of the application of the principles of prevention, recovery and disposal waste". High amount of WEEE is mainly caused by the linear economic pattern adopting "take-make-dispose" paradigm where the waste is disposed and disregarded for being further processed. To deal with this issue, the circular economy offers another approach. Due to the reverse part of its cycle as depicted in Fig. 1, the waste can be taken back and processed as the alternative supply source of production process. Among the waste flows considered, WEEE is viewed as the most hazardous but profitable one since it contains valuable materials and/or parts.

Being a part of reverse flow in closed-loop supply chain (CLSC), the disassembly process is the essential step enabling the circular economy. It is a set of activities aiming to extract the sub-assemblies, raw materials and/or other forms from end-of-life (EOL) products (McGovern and Gupta, 2011). The implementation of this process helps to enhance the sustainability of supply chain (SC) since it also practically promotes better employment and decreases the number of WEEE. Whilst augmenting the image of companies involved, it allows creating a market of EOL products. In compliance, the forward SC that is common form used on linear economy must be redesigned into CLSC by incorporating the reverse flow corresponding to WEEE.

However, the disassembly process remains expensive due to its complexity as time consuming endeavour and labour intensive (Ilgin and Gupta, 2011). Furthermore, collecting EOL products is considered as an indispensable process preceding the disassembly one. It is widely known that this transportation activity contributes to the increase on the total cost of SC. Compared to the assembly process that has been studied in decades, the supply side of disassembly process is less structured and more unstable so that it needs to be managed for avoiding inefficiency leading to high cost. Considering this process as a part of CLSC as shown in Fig. 2, dealing with the supply side of EOL products as a collection process may be expected. Thereby, incorporating the collection and the disassembly processes of EOL products in reverse SC context via an optimisation model is proposed in this paper.

The integrated logistical planning has drawn intention of both practitioners and researchers for proposing better forward SC. Particularly, it has been encouraged since the practice of the vendor-managed inventory and distribution (VMI/D).

In reverse context, the disassembly process is located in the reverse side preceded by the collection process. Motivated by Chandra and Fisher (1994) on the production–distribution

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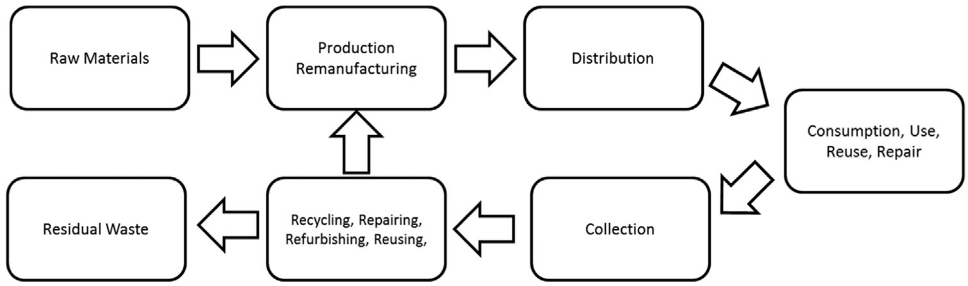

Fig. 1. The circular economy.

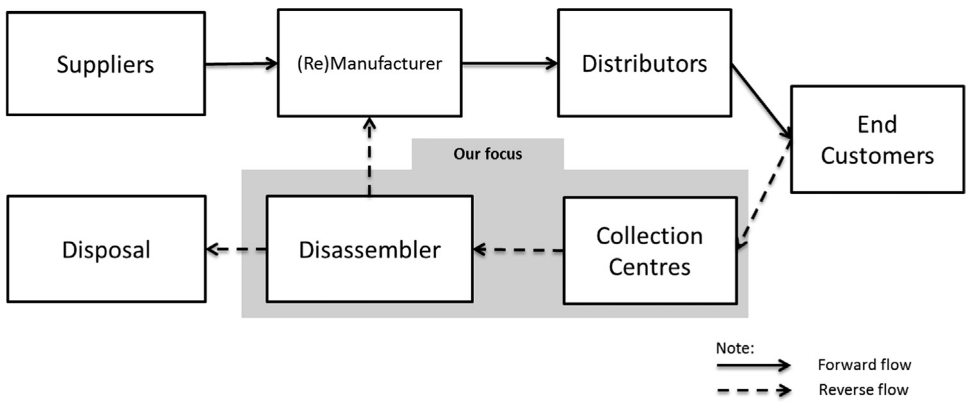

Fig. 2. Closed-loop supply chain.

problem (PDP), our work proposes an optimisation model coordinating the decisions on reverse side. PDP incorporates production and routing aspects in order to jointly optimise production, inventory and routing decisions (Díaz-Madroñero et al., 2015). In our case, the decision of collection and disassembly process is considered as the key point to diminish the total cost. To show it, the case with coordination and the case without coordination are compared in the experimental study which, henceforth, called as case I and case II, respectively.

Our work may be intended in the case where the reverse flow handled by a third-party reverse logistics provider (3PRL) due to the nature of disassembly process. Such circumstance is expected when (i) 3PRL performs better in term of speed, accuracy, cost and revenue on dealing with return process and (ii) few products returns and no dedicated personnel or procedures working on Stock et al. (2006). Moreover, it may lead to gain more economic efficiency for processes considered (Kumar and Putnam, 2008).

The remaining parts of this paper are organised as follows. The state-of-the-art is provided in Section 2. The optimisation problems are formalised in Section 3. Section 4 depicts the instance generation for the experimental study. The obtained results are analysed in Section 5. Section 6 gives the concluding remarks.

2. Literature review

After some industrial practices of VMI/D, e.g. Kellogg Company in Brown et al. (2001) and Frito-Lay's North America in Çetinkaya et al. (2009), the integrated logistical planning is favourable for proposing an SC with better performance. Particularly, the coordinated management of production and distribution process leads to the reduction of the total cost. It may take various configurations such as (i) integrated lot-sizing with direct shipment, (ii) inventory routing problem and (iii) production–distribution problem (PDP). The first problem minimises the total cost of setup, production, inventory and direct shipment while disregarding the routing aspect. The second problem exposes the decisions on routing aspect but ignores on production detail. Whereas, PDP focuses on both production and distribution aspects by incorporating the production decision and routing part in operational level decision as depicted in Fig. 3. We encourage the reader to see extensive review on PDP in Díaz-Madroñero et al. (2015) and Adulyasak et al. (2015).

As aforementioned, the circular economy requires a CLSC by embedding the disassembly and its corresponding processes to form the reverse flow. Compared to forward flow, its differences include geographical location, inventory and financial aspects. It deals with many dispersed collection centres as supply sources to collect EOL products and transport them to producer or recovery facilities such as disassembly facility or disposal area. Its lack of proven and effective inventory management leads to inconsistency. Additionally, unclear financial implication results on higher inefficiency (McGovern and Gupta, 2011).

However, as far as our knowledge, there is only few works considering integrated decisions which may lead to optimise the cost particularly on tactical/operational level ones. Özceylan and Paksoy (2014) and Özceylan et al. (2014) investigated the integration across strategic-tactical decisions in disassembly context. A mixed-integer non-linear problem was provided integrating the decisions of closed-loop network design and disassembly line balancing. Although the disassembly process has been extensively investigated in the literature, the majority of researches considered only single decision, e.g. lot-sizing (Barba-Gutiérrez et al., 2008), line balancing (Bentaha et al., 2014a, 2014b), sequencing problem (Yeh, 2012), inventory control (Godichaud and Amodeo, 2015), and RFID application (Ferrer et al., 2011). Thus, this work provides an integrated logistical planning in the next section focusing on the collection routing problem and the disassembly lot-sizing problem. Following our work (Habibi et al., 2014), this current work is the consecutive attempt of implementing such an integration into reverse context by considering collection routing and disassembly aspects.

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