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An efficient two-phase iterative heuristic for Collection-Disassembly problem

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ABSTRACT

Closing the loop in the supply chains is one of the mandatory conditions for more sustainable development. The Collection-Disassembly Problem appears in the reverse part of the closed-loop supply chains. Its aim is to coordinate the activities of collection of end-of-life products from collection centres and their subsequent disassembly. The disassembly step is required for efficient remanufacturing and recycling of returned products. The Collection-Disassembly problem integrates such optimization problems as dynamic lot-sizing and vehicle routing in general cases. In this paper, we develop a Two-Phase Iterative Heuristic to efficiently address large size instances. The numerical tests show that the heuristic provides good solutions under acceptable computational time.

1. Introduction

The implementation of closed-loop supply chains for electrical and electronic equipment (EEE) may have a sustainable impact in several ways. From the economic point of view, the returned products can provide cheaper components and materials resulting also in savings in energy, production and transportation costs. From the environmental point of view, the recovery of materials and components reduces the need for new (virgin) resources and avoids landfill. Recently, the 21st session of the Conference of the Parties (COP 21) 2015 held in Paris was one of the most important milestones to tackle climate change and environmental issues including waste electrical and electronic equipment (WEEE) minimisation. From the social point of view, it was also shown that the creation of new activities in reverse supply chains can be a source for new jobs in logistics and recovery.

A successful collection of EEE from the collection centres and their subsequent disassembly process are both important for the sustainable operations in closed-loop supply chains. By definition, the disassembly process aims to extract the components and subassemblies from End-of-Life (EOL) products (McGovern & Gupta, 2011) in order to satisfy customers' demands for remanufacturing and recycling processes. Referring to forward supply chains context, both collection and disassembly processes are counterparts of distribution and manufacturing processes, respectively. The coordinated management of these activities through Production-Distribution Problem (PDP) was proved to bring economic advantage (Chandra & Fisher, 1994). Similarly, the Collection-Disassembly Problem coordinating the collection and disassembly processes will lead to such an economic advantage as proved in our previous work (Habibi et al., 2017). This problem is especially relevant for Third-Party Reverse Logistics Provider (3PRLP) which is responsible to manage WEEE from its collection point until remanufacturing process or disposal. As an integration of dynamic lot-sizing and vehicle routing problem in general case, the problem studied in this paper is $\mathcal{NP}$-hard. To deal with large size instances, we develop an efficient heuristic method.

The paper is organized as follows. The state-of-the-art is provided in Section 2. The optimisation problems are formalised in Section 3. Section 4 contains the description of the solving method developed. The obtained results are provided and analysed in Section 5. Section 6 gives concluding remarks.

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2. Literature review

To the best of our knowledge, the Collection-Disassembly Problem was initially introduced and formulated in Habibi et al. (2017). Fig. 1 depicts the decision levels about the collection of end-of-life products and their disassembly leading to the fulfilment of customer demands in different types of components and subassemblies. In recent years, a lot of scientific attention has been attracted to the disassembly process. Existing researches mainly focus on single level decision such as lot-sizing (Barba-Gutiérrez, Adenso-Díaz, & Gupta, 2008), line balancing (Bentaha, Battaïa, & Dolgui, 2014a, 2014b), sequencing problem (Yeh, 2012), inventory control (Godichaud et al.), RFID application (Ferrer et al., 2011). However, the integration with the collection problem was rarely considered despite the fact that it was shown to improve the overall benefit. The study of Habibi et al. (2017) evaluated the performances of available commercial solvers to tackle the problem instances of different level of difficulty. The authors concluded about the necessity to develop an efficient approximate method to deal with large size instances.

Since there is no such method available for the Collection-Disassembly Problem, we conduct our literature analysis on the similar works in PDP for forward supply chain context. Essentially, PDP is a problem focusing on both production and distribution aspects as depicted by Fig. 2. It integrates the production decision (dynamic lot-sizing problem) and vehicle routing throughout a planning horizon in operational level decision. It is widely concerned by those who works on Vendor Managed Inventory and Distribution (VMI/D) such as Kellogg Company and Frito-Lay's North America (Brown, Keegan, Vigus, & Wood, 2001; Çetinkaya, Üster, Easwaran, & Keskin, 2009).

The first PDP formulation was proposed by Chandra and Fisher (1994). Since then, an alternative formulation was proposed in Archetti, Bertazzi, Paletta, and Speranza (2011) emphasizing the use of so called the order-up to level (OU) and the maximum level (ML) policies. The OU policy implies that the quantity of products shipped to the customer at the maximum level of its inventory capacity. Whereas the ML policy imposes that the quantity shipped is such that the inventory level is not greater than its capacity. Another formulation using Miller-Tucker-Zemlin subtour elimination constraints from Desrochers and Laporte (1991) was studied in Boudia, Louly, and Prins (2007) and Boudia and Prins (2009). PDP under uncertainty was considered in Adulyasak, Cordeau, and Jans (2015) and solved using stochastic programming. A multi-objective PDP considering multi-vehicle, carbon footprint and time windows was proposed in Kumar et al. (2015).

The current trends of researches in PDP is to propose more efficient solving methods for available data sets of Archetti et al. (2011) and Boudia et al. (2007) and Boudia and Prins (2009) such as exact methods (Amorim, Belo-Filho, Toledo, Almeder, & Almada-Lobo, 2013), Branch & Price (Bard & Nananukul, 2010), Branch & Cut (Archetti et al., 2011; Adulyasak, Cordeau, & Jans, 2014), Mathematical Programming-based Heuristics (Archetti et al., 2011), Lagrangian Relaxation (Fumero & Vercellis, 1999), Decomposition Heuristics (Bertazzi, Paletta, & Speranza, 2005; Chandra & Fisher, 1994; Chen, Hsueh, & Chang, 2009; Çetinkaya et al., 2009) and L-Shaped (Benders) Decomposition (Adulyasak et al., 2015). Some (meta) heuristics were also proposed such as Tabu Search (Shiguemoto & Armentano, 2010), Genetic Algorithm (Buer, Woodruff, & Olson, 1999), Greedy Randomized Adaptive Search Procedure (Boudia et al., 2007), Memetic Algorithm (Boudia & Prins, 2009), Ant Colony Optimization (Calvete, Galé, & Oliveros, 2011), Adaptive Large Neighbourhood Search (Adulyasak et al.) and Two-Phase Iterative Heuristics (Absi, Archetti, Dauzère-Pérès, & Feillet, 2014). To the best of our knowledge, Two-Phase Iterative Heuristics provide the best solutions for all available instances. Readers are suggested to read (Adulyasak, Cordeau, & Jans, 2015; Díaz-Madroñero et al., 2015) for further review in PDP.

The analysis of the literature suggested to use the solving method proposed in (Absi et al., 2014) as a basis for an efficient approximate method for Collection-Disassembly Problem. Before the presentation of a new method developed, a detailed problem formulation is given in the next section.

3. Problem definition

A single disassembly site having a capacitated inventory is responsible for gathering a single type of EOL products available at dispersed collection centres. A vehicle with fixed capacity is available for collecting the products under full truck load policy.

The structure of product is known: it contains several components with known and deterministic quantity. The disassembly process releases all the components from a product. The capacity

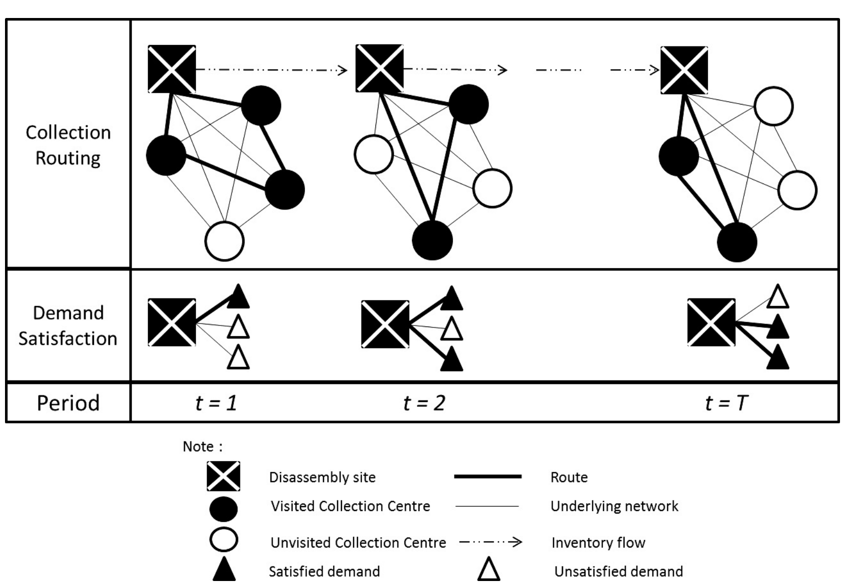

Fig. 1. Representations of our problem in Habibi et al. (2017).