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A Genetic Algorithm for Reverse Logistics Network Design: A Case Study from the GCC

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Abstract
Reverse logistics (RL) involves a sequence of operations that initiate at the consumer level and terminate at the manufacturer, opposite to the traditional forward approach of the supply chain. Recycling, reuse, and re-processing of products are activities of RL networks, all of which are becoming increasingly prevalent due to growing environmental and socio-economic concerns. Research has begun to study such networks in an effort to maximize efficiency and to improve operations. Previous work focused on developing a Mixed Integer Linear Programming (MILP) with an aim of determining the optimal location and capacity of important nodes of the RL network, such as inspection centers and remanufacturing facilities. Transportation decisions, such as whether to use in-house or outsourced vehicles, are often based on cost effectiveness. The problem is formulated for the case of a household appliance in the Gulf Cooperation Council (GCC) region. Sixty-eight cities are considered, leading to a very large number of variables and constraints; thus, a heuristic approach, namely a Genetic Algorithm (GA), is chosen to solve the problem. The main contribution of this paper is to develop a very efficient GA capable of solving a large scale problem in short time. The developed GA was capable of solving a very large problem (with 656,885 continuous variables, 2,040 binary variables, 10 integer variables, and 100,340 constraints) with a gap of 0.3% and about 38.5 times faster than GAMS using a personal computer. The same GA succeeded to solve both large and small problems to optimality or with a gap that didn’t exceed 1.5% and faster than GAMS. The technique that we used to code the GA reduced the number of variables and constraints to 92% and 86%, respectively. Furthermore, the reported results provide important insights on practical aspects of the problem, as well as useful points for the evaluation of the heuristic’s performance.

Keywords: Reverse Logistics; Remanufacturing; Genetic Algorithms; Mixed Integer Programming; Metaheuristics.

1. Introduction
The field of Reverse Logistics (RL) is concerned with retrieving a product at the end-of-life time from the customer and delivering it to the manufacturer through a series of points such as collection and inspection centers, with the purpose of properly disposing of the product or recovering additional value from it (Prahinski & Kocabasoglu, 2006). This field of operations has received increasing interest for many reasons. To begin with, the amount of returned products is constantly growing, along with the environmental conscience of consumers (Keyvanshokooh et al., 2013). In addition, secondary markets thrive on the premise of discarded products (Prahinski & Kocabasoglu, 2006). Another important factor enforcing end-of-life product use is the introduction of rules and regulations obliging companies to take measures for the proper handling of returned products (Toffel, 2003). These measures, as well as the
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