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Design of Sustainable End-of-life Vehicle recovery network in Egypt

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Abstract This paper presents the design of a sustainable recovery network for End-of-life Vehicles (ELVs) in Egypt. A lexicographic mixed integer goal programming approach is proposed for modelling the problem. The deliverables of the proposed mathematical model include: locations for the different facilities and the amount to be allocated to the different End of Life (EOL) options.

LINGO® is used for solving the proposed model. The obtained results have been analyzed to elicit information about the design of the recovery network and the corresponding product-oriented legislation.

1. Introduction

The increasing concern about the environment has initiated a large set of regulations concerning the manufacturing and disposal of products. Vehicles are one of the critical products causing a considerable environmental burden during the phases of usage and disposal. Yet, large environmental and economic benefits may be expected when applying an appropriate recovery strategy. A vehicle is a complex product consisting of a variety of materials. The estimated composition of an average car manufactured in 1985 is indicated in [1]. Ferrous material, which is a perfect candidate for recycling, is the major component of a vehicle accounting for 71% of a vehicle's weight. Other major materials included in the vehicle are plastics, non-ferrous metals, rubber, glass and fluids contributing to 8%, 7%, 5%, 3%, and 2%, respectively.

The European Union (EU), Japan, Korea and Taiwan present examples of countries having a product-oriented legislation has been initiated to control the recovery of End-of-life Vehicles (ELVs).

In the EU the automotive recycling industry exists as a profitable industry since the fifties. The need for environmental

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legislation was driven by the concern of the ever shrinking landfill capacities. About 8–9 million ELVs per year are estimated to be recycled in the EU countries. The Directive 2000/53/EC has been adopted.

In Japan, the ELV Recycling Law came into force in 2005 to deal with an estimated value of 5 million ELV produced annually. This number includes locally manufactured and imported vehicles. The law obliges manufacturers and importers to take the responsibility of their products through collection and recycling operations.

Guided by the European directive, Korea issued the Act for Resource Recycling of Electrical and Electronic Equipment and Vehicles on April 2, 2007. The act came into force as from 1 January 2008. The act promotes the following activities for electrical and electronic equipment and vehicles: (a) the recycling of EOL products, (b) the design for the environment and (c) the restriction of hazardous substances and the appropriate treatment of their waste. Around half million ELVs are generated every year in Korea. Eighty thousand ELVs are exported as second-hand cars, and the remainders are collected at junkyard facilities. ELVs are collected with a payment of 117 US$ per car made on average to the car owners in Korea, since they are still recognized as valuable materials and able to provide some profit during the dismantling process [2]. The actors involved in the Korean ELV management system system are vehicle owners, ELV collection agencies, dismantlers, shredder and recyclers, and part reuse dealers.

Taiwan is a further example of a country establishing an ELV management system. Prior to 1994, the recycling of ELVs in Taiwan was performed by related operators in the industry. Since the publishing of the ''End-of-life Vehicle recycling guidelines'' under the authority of the Waste Disposal Act by the Environmental Protection Administration (EPA) in 1994, the recycling of ELVs in Taiwan has gradually become systematic. Subsequently, the Recycling Fund Management Board (RFMB) of the EPA was established in 1998 to collect a Collection–Disposal–Treatment Fee (recycling fee) from responsible enterprises for recycling and related tasks. Since then, the recycling channels, processing equipment, and techniques for ELVs in Taiwan have gradually become established [3].

Developing countries on the other hand are lagging in the establishment of product-oriented legislation. Due to economic and social circumstances, minimal concern has been devoted to the recovery operations. Nevertheless, evolving global environmental awareness, shrinkage of landfill area, and depletion of natural resources are among the factors which have driven a number of developing countries in adapting strategies towards product recovery.

The design of a sustainable recovery network is an essential strategic decision for developing countries at this early stage of implementing ELV recovery operations. Due to the economic and social aspects as well as the absence of product-oriented legislation the design and operation of the recovery network differ from their counterpart in industrialized countries. For this reason, approaching the network design problem from the perspective of developing countries is of vital importance.

The remainder of this paper is structured as follows: Section 2 describes the current status of ELV recovery operations in Egypt. Section 3 presents previous work of ELV recovery network design. The design problem is mathematically formulated in section four and its solution presented in section five. Finally, conclusions are drawn and areas for future research are suggested.

2. ELV recovery in Egypt

According to the report published by the Industrial Development Authority [4], over the last 20 years the vehicle assembly sector has expanded from 3 assembly plants, which relied almost exclusively on imported components, to 17 businesses employing 27 assembly lines to manufacture a range of passenger cars, light commercial vehicles, trucks and buses. Vehicle assembly production continued to expand and reached 101,319 vehicles in 2007; increasing by 118% from 2003. Over 360 factories manufacturing a range of automotive components. Egygptian Automotive Manufacturers Association (EAMA) data show that total vehicle demand in the Egyptian market increased from 70,834 units in 2003 and reached over 227,488 units in 2007. An increase over 200% in 5 years [5]. Recently there has been a growth in automotive market due to the variety of financing schemes made available by vehicle distributors and banks. Nevertheless the old cars are usually not abandoned, but sold on a second hand market to continue its usage stage. In order to have an idea about the structure of the Egyptian vehicular fleet, the following data are presented based on the report published by the Information and Decision Support Center [5]. More than the quarter of the current registered vehicles is more than 30 years old. This gives an indication that the registration of new car does not mean the deregistration of an old car. The latter continues circulation by another owner. The previous value also points out to the elevated amount of pollution generated. Private cars constitute approximately half of the number of all vehicles. According to the Ministry of Interior Affairs, 26.4% of circulating cars are older than 30 years. A 25% of the circulating cars are manufactured in the period between 1980 and 1990. These numbers give an indication about the amount of pollution caused by operating these vehicles. Furthermore, 36.1% of all the vehicles are located in large cities.

As to ELV practices, they exist but they are scattered and unsystematic. The current ELV practices are limited to scattered small sized workshops and scrap yards. Fig. 1 depicts the route of ELV in this category. The arrows represent the material flow through the network. Money flow goes in the opposite direction of material. It is observed that unlike other industrialized countries the export option of ELVs is not present. This is because the majority of industrialized countries set high standards for the circulation of used cars. In developing countries used cars don't meet these standards due to the excessive usage. While in the European Union the lifetime of a vehicle is estimated by 10–14 years, the lifespan of a vehicle

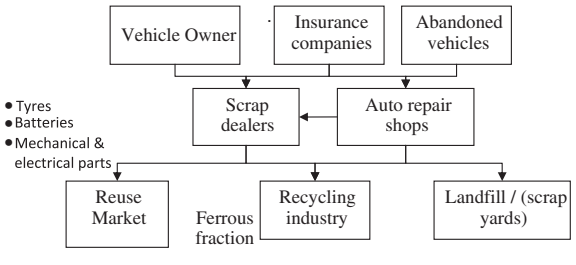

Figure 1 Typical ELV path in Egypt.