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# Official recycling and scavengers: Symbiotic or conflicting?

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ABSTRACT

Nowadays, especially in developed countries, the traditional collection of end-of-use products by scavengers has been displaced by formal waste recovery systems. However, scavenging still exists, especially in places with collection capacity shortages and/or low living standards. Besides its obvious social implications, the financial and environmental aspects of scavenging are certainly not trivial. Informal recycling of waste electrical and electronic equipment (WEEE) by scavengers not only constrains profits of the formal system. In their effort to recover the value of end-of-use products, scavengers also pollute the environment if toxic substances leak when WEEE is not properly disposed of. We investigate the impact of scavenging on the operations of the formal recovery system of WEEE, under three regulatory measures, using system dynamics methodology. By using data from a real world closed-loop supply chain that operates in Greece extended numerical experimentation revealed that a legislation incorporating scavengers into the formal waste recovery system (instead of either ignoring or prohibiting their participation) is beneficial for economical, environmental and social sustainability.



## 1. Introduction

Recently, mass consumption and shortening lifecycles of consumer products have increased worldwide production of goods and led to indiscriminate disposal habits. The usage rate of raw materials is increasing and available landfills are filling up. One of the major and fastest growing waste streams in the world is that from waste electrical and electronic equipment (WEEE), which also appears as one of the biggest sources of environmental footprint (Neto et al., 2010).

WEEE contains toxic substances such as lead, cadmium and mercury. While these toxins are embedded inside the appliance and separated from the user during usage, concerns have been raised regarding the environmental risk associated with toxic substances leaking when WEEE is disposed of in landfills (Williams et al., 2008). Nearly 40% of the lead disposed in landfills and 50% of the lead in incinerators comes from WEEE (Toffel, 2003). It is estimated that the amount of WEEE in Europe increases 16%–28% every year and by the end of 2010 it would be about 4 kilograms per resident totalling approximately 12 million tons (Widmer et al., 2005).

Despite stringent environmental regulations (Mitra, 2007) imposed by governments, through increased collection and recycling percentages (Directive 2002/96/EC, 2003; Chen and Monahan, 2010), informal waste recycling activities are still carried out by specific social groups. The informal recycling sector ("grey" recycling) refers to the waste recycling activities of scavengers (Medina, 2000) and covers a significant part of the total recycling sector both in developed [e.g. Germany by handicapped people (Tobias, 2009)] and developing countries [e.g. Mexico].

Scavenging is a widespread phenomenon with environmental, economical and social dimensions. Scavengers are usually people with limited employment potential who make their living by collecting all kinds of materials for reuse or recycling and by directly extracting recyclable and reusable materials from waste. However, the participation of scavengers often creates a barrier to formal waste recovery operations. In Greece it is estimated that about 90% of WEEE between 2003–2006 was processed by "grey" recycling (Antonopoulos and Karagiannidis, 2007).

Most researchers [with very few exceptions (Medina, 2000; Wilson et al., 2006)] have ignored scavenging in their studies of reverse supply chains and official waste streams. Therefore, many of these studies may be practically irrelevant, especially in countries where grey recycling is substantial.

The formal waste recovery system regards scavenging as potentially harmful to public health. Some regulatory authorities declare scavenging as illegal, while others ignore informal recycling hoping it will disappear in the foreseeable future (Medina, 2000). However, given the economical crisis, the limited employment opportunities and the living conditions of scavengers throughout the world, this hope could be considered idle.

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Studies on scavenging concentrate on problem identification, driving forces, cause-effect and social impact, but from a qualitative point of view. In this paper we develop a holistic approach to comprehend the interactions of scavenging with formal waste recovery systems and to study the impact of scavenging on environmental, economical and social aspects of sustainability. We develop a comprehensive dynamic closed-loop supply chain (CLSC) model which enables the joint examination of formal and grey recycling operations. In particular, we consider a WEEE recovery system imposed by legislation and study the impact of the regulatory measures, the scavengers' activities and the formal waste recovery system activities. The selected methodological tool is System Dynamics (SD). To estimate parameters we apply the model to recycling activities in Central Macedonia in Greece.

The innovative elements of our work are twofold. Firstly, we study the impact of scavenging on the operations of a WEEE recovery system through the environmental dimension (availability of natural resources and landfills, and pollution due to leaks from the scavengers' uncontrollable disposal ignoring the pollution due to emissions), the economical dimension (CLSC profitability) and the social dimension of sustainability (number of unemployed scavengers). Secondly, we assess the efficiency of different regulatory measures in limiting the impact of informal recycling on the economical, environmental and social aspects of sustainability. We study the efficiency of three different regulatory measures; the current "real" system in which the legislation ignores scavenging, the "ideal" system where the informal recycling sector has disappeared as a result of the legislation, and the "symbiotic" system where the legislation supports scavenging as symbiotic to the formal system. The above analysis is performed by extended numerical investigation with parameter values at different levels in combination with Analysis of Variance (ANOVA) to analyse the sensitivity of the system.

The next section presents a literature review of studies describing the impact of scavenging on societies, along with a brief presentation of SD methodology. In Section 3 we present the structures of the "real", the "ideal" and the "symbiotic" system. In Section 4 we implement the model in a real-world CLSC with recycling activities of EEE in Greece, while in Section 5 we conduct sensitivity analyses to study the impact of alternative regulatory measures on the sustainability of the CLSC. Section 6 suggests future research directions and the final section provides a summary of the results.

## 2. Literature review

Many studies have presented the impact of scavenging and the cause-effects at a city level. In cities within developing countries 50%–80% of the waste generated is usually collected, with open dumping as the only available disposal method. The World Bank has estimated that in developing countries about 1% of the population makes a living by scavenging. Scavengers usually live near landfills to have easy access to and reduce transportation costs of the discarded materials (Brunner and Fellner, 2007). In Dhaka city waste recovery is performed by more than 100,000 scavengers, in Calcutta by 20,000, in Manila by 12,000 and in Mexico City by 15,000. Informal recyclers often belong to poor and often badly educated marginalised social groups or minorities, like the Pepenadores, Catroneros and Buscabotes in Mexico, Basuriegos, Cartoneros, Traperos and Chatarreros in Colombia, Harijans in India, Chamberos in Ecuador, Buzos in Costa Rica, Cirujas in Argentina, Roma people in Europe and Zabbaleen (Christian minority) in Egypt (Medina and Dows, 2000).

In Third World cities that lack municipal waste collection, scavengers play the role of formal collection systems using different transport means. In Santa Cruz (Bolivia) scavengers serve about 37% of the population, in Dhaka city (Bangladesh) more than 50%, while in Damascus (Syria) thousands of scavengers serve 10% of the population. In some Indian communities, informal collectors charge a fee to residents for picking up their garbage and for cleaning the street in front of their houses. Scavenging is largely facilitated by insufficient collection and improper disposal in open landfills. Brunner and Fellner (2007) studied how various economic conditions determine waste management strategies, concepts and measures. They consider three distinctly different regions regarding economic conditions (Vienna, Damascus, and Dhaka) and conclude that the less developed countries do not have the same economic capacity for the collection and treatment of their waste. The health risk for inhabitants having direct contact with waste can only be reduced by introducing formally structured collection services. However, the income of thousands of scavengers would be cut by this measure.

The improper waste disposal constitutes a source of land, air and water pollution, and poses risks to human health. Half the collected waste is dumped illegally in vacant lots or openly burned in residential areas, practices associated with major health hazards for people living in these neighbourhoods (e.g. hygiene problems, spreading of diseases, smoke emissions, etc.) (Brunner and Fellner, 2007).

The health and safety risks for the scavengers are even more acute given that they usually live on or next to landfills. Another social dimension is that scavengers, due to their way of life, often constitute a subject of harassment to the authorities and police as their activities are considered unhygienic (Medina and Dows, 2000). The informal sector is largely unregulated and unregistered (Wilson et al., 2006). Therefore, scavengers or informal sector enterprises do not pay taxes, have no trading license and are not included in social welfare or government insurance schemes. The informal system also constitutes a very efficient and hard competitor of legal collection and recovery systems.

However, scavenging can render significant social and economical benefits. Firstly, if addressed properly, it can be "symbiotically" incorporated into the formal waste recovery system. This incorporation (a) will improve the efficiency of the formal system, (b) will help the implementation of environmental regulations (such as the Directive 2002/96/EC, 2003), (c) will save energy while generating less pollution than the procurement of virgin materials (especially in developing countries where the formal system has limited capacity), (d) will reduce the required collection and disassembling capacity, and their costs, (e) will create jobs for unskilled individuals, and (f) could stop illegal dumping by holding scavengers accountable for their actions and creating incentives to bring the collected products to specific places. Secondly, this "symbiotic" incorporation will likely decrease the unemployment and crime rates (Medina, 2000).

Although scavenging is an issue that appears both in developing and developed countries, affecting operations and in some cases even viability of formal waste recovery systems, rarely is a comparison performed of the costs and benefits of incorporating scavengers into the formal system (Medina, 2000). In this paper we develop a mathematical model to comprehend the interactions of scavenging with the formal waste recovery system and to investigate the impact of different regulatory measures on the system's sustainability.

In the field of quantitative research, recycling operations have been studied using various approaches. For example, Krikke et al. (2003) develop an operations research (OR) model applied to a refrigerators' closed-loop supply chain that aims at cost minimisation, energy use and waste produced by the supply chain's operations. Atasu et al. (2009) study the impact of WEEE legislation on the reverse logistics operations. Biehl et al. (2007) simulate a