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System dynamics model for optimizing the recycling and collection of waste material in a closed-loop supply chain

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ABSTRACT

To meet the immediate environmental challenges and sustainable development, Closed-loop Supply Chain (CLSC) management has become increasingly important and urgent. This is in lieu with some severe problems such as global ecological damage, resource wastages and shortages and pollution of the environment, and discretionary exploitation of natural resources. On the other hand, re-manufacturing of used merchandise and bringing them back to the market provides environmental and customer benefits to Original Equipment Manufacturers (OEMs), in addition to cutting back their production cost. This paper aims at evaluating the system behavior of an electrical manufacturing company as a case of study, by using System Dynamics (SD) simulating of Closed-loop Supply Chain (CLSC). VENSIM PLE software developed the simulation model. Based on the initial result, customer satisfaction and Green Image Factor (GIF) are lacking in the system. Therefore, to tackle this issue, an improvement model with a collection center was proposed. Results derived from the improved model presented a data of which the demand backlog level fell by 21.19%. Furthermore, the customer satisfaction in the system rose by 21.6%. In addition, as a result of an increase in GIF level from 14.80% to 48.1%, the return products rate rose from 184 items to 614. The method in this research can be used to investigate a variety of CLSC systems and their effects before implementing them in real life.

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1. Introduction

From the 20th century, the economy of the world is developing at an alarming rate and concurrently, discretionary exploitation of natural resource has led to some distinct problems, for instance, global ecological degradation, resource wastages and shortages, environmental pollution and so forth. Mass consumption and indiscriminate disposal habits have revealed our planet's limitations [1,2]. Also, Industrial Economies have produced enormous amount of waste; available landfills are quickly filling up and new ones cannot be located [3]. In several countries, manufacturers are required to take the responsibility for the whole process of product life cycle, especially in recycling and reusing of treatment of waste products. Because of several established and emerging reasons; diminishing non-renewable resources, stricter regulations related to environment and occupational safety/health, increasing consumer preference for environmentally-friendly products, etc. [4], there is now a well-recognized need for achieving overall sustainability in industrial activities. Therefore, recycling of used products and bringing them back to the market provides not only the environmental and customer advantages to Original

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Equipment Manufacturers (OEMs) but also reducing their production cost [5]. Manufacturers can save about 40–60% of the cost while paying for only 20% of the manufacturing effort when compared to normal production, [6]. The production, planning and network design of CLSC concept has attracted the attention of researchers and managers [7]. This is owing to the fact of revolution in sustainable and green manufacturing. In many industries, OEMs are looking for efficient ways to integrate reverse logistics into their supply chains, to recover economic value from rejected products and to reduce disposal costs [8,9]. In recent years, [10] state environmental issues have become a critical topic. In addition, by considering the dimensions of sustainability, [11] states the significant of social factors, and [12,13] reiterated on environmental factors.

A supply chain is conventionally considered as a line, beginning from the movement of goods from suppliers to manufacturers. Then it moves on to wholesalers, retailers, and finally reaching consumers through these distribution ports. Nowadays, supply chain designs tend to become circular to form the closed loop rather than being linear because of the improvement in the interaction between the ends of this line. Hence, complex industrial relationships prove the existence of material flows not only downstream, but also upstream during the production, distribution, and consumption stages [14,15]. Also, all supply-chain activities, including the reverse chain, generates emissions, pollution, and waste via diverse processes in the environmental chain. Eventually, an (negative) impact on natural resources is seen. As these natural resources are vital inputs for the supply chain, it is necessary for firms to include environmental criteria in their product and supply-chain design, and also for countries to come up with environmental policies to upkeep the balance of nature and the continuity of supply chains. Reverse logistics is defined as the process of moving goods from their typical final destination for the purpose of capturing value, or proper disposal which covers all manufacturing and logistics activities including re-using, re-manufacturing, recycling, and managing hazardous materials [16]. Additionally, attempts for managing both forward and reverse flow in a supply chain are studied in the context of a CLSC. Establishing an effective and efficient system for any type of material flow in the supply chain pertaining to environmental and economic concerns is the main study of CLSC design. The pivotal challenge in CLSC design is the closeness of the chain. This can be measured by the amount of waste that it produces. In other words, if and only when it generates lesser waste than previously, then only the supply chain gets closer [15].

Another important issue is the integration of the environment, economic, and social features of industry in that setting based on the assistance of sustainable supply chain management. Due to the lack of research about customer satisfaction and environmental factors, the necessity of promoting the design and managing the sustainable supply chain becomes very clear [4]. In today's competitive market, every organization has made customer satisfaction as one of the important focused areas, and also, because of the restrictions from the government in bearing responsibility regarding proper disposal, have forced the manufacturers to concentrate on CLSC system and decreasing the cost.

As a result, researchers have not covered enough on increased waste and reduced customer satisfaction in CLSC due to the internal and external factors impact by SD approach. Therefore, there is a need to give special attention to this precise area of the supply chain and because of that the objective of this paper is to investigate the customer satisfaction factors and GIF in the CLSC system of an electrical manufacturing company. An SD model is developed to handle the dynamics of CLSC to succeed in this goal. It covers two dimensions of sustainability; whereby one takes into account social factors which leads to customer satisfaction and the other, minimizing the environmental issues.

2. Literature review

2.1. Supply Chain Management (SCM)

According to [17,18], SCM is defined as a collaborative method to commerce through the planning and control of materials and information of dealers to end clienteles. Studies on SCM consumers reached from analytical meaning show the supply chain as networks of material dispensation cells as considered by [19] to examinations of supply chain companies as mentioned by [20] and client facility according to [21]. SCM frequently mentions either on a process-oriented management method in obtaining, making and transporting goods and facilities to close consumers or in a broader sense, to the organization of the various performers fitting to the same supply chain referring to [22,23]. According to [24], SCM signifies a junction where a wide variety of academic punishments have met. To elaborate further, Fig. 1 presents the schematic view of the supply chain network.

2.2. Closed-loop Supply Chain (CLSC)

As considered by [26], very few strategic management difficulties in CLSCs had been examined and were stated in the prose, noticeable by the year of 2000. [27], offered two case researches that SD had conducted to model Reverse Logistics – (RL); meaning the flow of used crops back to the production environment difficulties. An existing production and retrieval system by SD was presented by [28]. Moreover, [29] improved the existing main effect loops and also, improved a dynamic model to assess the ramification of environmental subjects on long-term decision making sector in assortment and re-manufacturing doings. Hence, [30] introduced an SD model absorbed on cars illustrating that the understanding of the legislation board's compulsory of the European Union (EU) is dependant on the produced project.

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