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Efficient flexible long-term capacity planning for optimal sustainability dimensions performance of reverse logistics social responsibility: A system dynamics approach

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ABSTRACT

Product lifecycle uncertainties in Closed-Loop Supply Chains (CLSCs) are costly and frequently unavoidable. So the aim of this paper is to develop efficient flexible long-term capacity planning policy for CLSCs that considers social responsibility or a supply chain with Reverse Logistics Social Responsibility (RLSR). This aim is to answer an important research question on how to tackle the lifecycle with its inherited uncertainty to achieve optimal sustainability dimensions performance. Here, a single-product System Dynamics (SD) model of the supply chain with RLSR is used. This SD model considers interrelated sustainability dimensions and adopts the product lifecycle with its inherited uncertainties, such as the length of the product lifecycle, pattern of the product lifecycle, and residence index. Finally, a mathematical model of the developed policy is constructed and a simplified non-linear multi-objective algorithm is proposed to solve this mathematical model. In addition, Taguchi Design is used to minimize the number of simulations needed in the numerical experiment. The findings of this study show that the developed policy could be used to tackle the lifecycle with its inherited uncertainty to optimize the sustainability dimensions performance. These findings have some limitations, however. The findings underscore this paper's contribution to the relatively limited but important academic knowledge on capacity planning development for research on social responsibility issues in CLSCs. In practice, the results will give managers a better understanding of how to tackle product lifecycle uncertainties in RLSR and will therefore lead to better capacity planning to achieve optimal sustainability dimensions performance.

1. Introduction

This paper proposes a concept of social responsibility by considering both company and consumer in the supply chain as entities that are organisms (Caruana and Chatzidakis, 2013; Lozano et al., 2014). This concept has a close relationship with ISO 26000 (Castka and Balzarova, 2008; ISO, 2015). But unlike ISO 26000, here the social responsibility focuses on “mutualism”, which represents the balance between the rights and responsibilities of both company and consumer in the supply chain for sustainability.

Reverse Logistics Social Responsibility (RLSR) is preferred as the integrated social responsibility activity in supply chains (Sarkis et al., 2010; Sudarto et al., 2014). RLSR is a type of Reverse Logistics (RL) that is conducted in the supply chain as a voluntary integrated social responsibility activity. RLSR involves most actors in the supply chain who have an impact on social responsibility (Ciliberti et al., 2008b). RLSR involves both companies and customers in the supply chain, who need to perform social responsibility due to the impact of their activities, which influence both the environment and society (Caruana and Chatzidakis, 2013). In addition, involving as many actors as possible in the supply chain is critical since social responsibility performance among actors affects the other actors' performances (Cruz, 2013; Formentini and Taticchi, 2014).

For the best of our knowledge, interrelated sustainability dimensions can reveal a new drawback compared to classic sustainability dimensions (Seuring et al., 2008). In contrast to classic sustainability dimensions: independent dimensions of economic, environmental, and social (Elkington, 1999; Nikolaou et al., 2013), the interrelated sustainability dimensions (economic, environmental, and social) are not independent but interact with each other. This feature reveals a new advantage: that by considering the trade-off among sustainability dimensions, the interrelated benefits and disadvantages of each sustainability dimension could be earned (Sudarto et al., 2016). So in relation to social responsibility in the supply chain, the interrelated

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sustainability dimensions could give a clear answer to the important question of how economic return could emerge from social responsibility activity (Ciliberti et al., 2008a).

Capacity planning in RL, regarding expansion and contraction of collection and recycling capacities, involves complex issues (Georgiadis and Athanasiou, 2010). The uncertainty inherited from the RL due to the variability of a product's usage period, along with the unknown reusability, the breakdown rate, and the recycling rate of the used products, makes the decision-making process about the capacity policies a difficult task to accomplish. This uncertainty entails a higher risk of shortage of end-of-use product returns, since supply may vary and the dismantling volume may turn out to be lower than predicted. This will cause the overcapacity phenomenon in capacity planning, which, in the long run, may negatively affect the profitability, especially in high capacity acquisition conditions (Georgiadis and Athanasiou, 2013). So there is a close relationship between complex issues in the capacity planning and product lifecycle; for example, the case of Pack2-pack shows that capacity planning in the reverse channel of Closed-Loop Supply Chains (CLSCs) can impact the lifecycle of product families produced in the forward channel (Georgiadis and Athanasiou, 2013; Sudarto et al., 2016).

The decision to expand or contract capacity is associated with important questions that need to be answered, such as when, where, and how much to expand/contract. However, the capacity planning in RLSR is more complex than that in common RL. As RL is a social responsibility activity, the decision to either expand or contract is now constrained by the existence of a social responsibility fund that is generated from the premium price borne by the consumers (Hsueh and Chang, 2008; Sudarto et al., 2014). Moreover, in RLSR it is necessary to consider the interrelated sustainability dimensions that affect not only the economic but also the environmental and social performance. Therefore, the capacity planning in RLSR becomes much more than a trivial exercise.

The aim of this paper is to develop efficient flexible long-term capacity planning policy for RLSR by using the system dynamics (SD) approach. The model is single-product. Fig. 1 shows the flow diagram of the methods used in this paper. The SD approach is used since the supply chain under this study is complex and the system under study is dynamic and limited by feedback. So, SD is preferred compared to optimization to avoid the occurrence of infeasible solutions (Hsueh, 2014). The term “efficient” refers to the allocation of a limited social responsibility fund (Sudarto et al., 2014), while the term “flexible” refers to the adaptability (Bai and Sarkis, 2013; Georgiadis and Athanasiou, 2013) to tackle the lifecycle with its inherited uncertainty. So, the efficient flexible capacity accommodates the need to become adaptable to uncertainty with a limited social responsibility fund. Here, the developed capacity planning policy works together with the social responsibility level policy (Hsueh and Chang, 2008; Sudarto et al., 2014). The considered inherited uncertainties include the product Lifecycle length (L), its return Patterns (P), and the Residence Index (RI) (Georgiadis et al., 2006). Last, the interrelated sustainability dimensions performance is measured to find out the policy impacts. This part of study will answer the important question of how to tackle the lifecycle with its inherited uncertainty for optimal sustainability dimensions performance. In addition, the Taguchi design of experiment is used (Antony, 2003; Ramachandran and Tsokos, 2015) to minimize the number of simulations needed in the numerical experiment. One good example of a real-world practice that is comparable to the social responsibility concept in this paper is the automotive-related recycling law in Japan issued by the Japanese Ministry of the Environment (http://www.env.go.jp/en/laws/recycle/).

The constructed SD model is closely similar to Sudarto et al. (2016), except for the aim of the research, its capacity planning, and the policy parameter settings as shown in Fig. 1. Unlike in this paper, they are focusing their research on impact of behavior analysis due to product lifecycle in RLSR. As the consequences, they are using different approach of efficient flexible capacity planning policy and different policy parameter settings (noise factors/outer array).

The paper is structured into the following sections. First, it presents the introduction. Second, it discusses the seminal works in capacity planning for RL and RLSR. Third, it explains the efficient flexible long-term capacity planning. Fourth, it discusses the experimental design. Fifth, it presents the results and discussion. Last, the conclusions and possible future direction are discussed.

2. Capacity planning in reverse logistics and reverse logistics social responsibility

2.1. Social responsibility in the supply chain

Poor social responsibility performance of any player in the supply chain may damage the reputation of the corporation at the center of focus, such as in the cases of McDonalds, Mitsubishi, Monsanto, Nestlé, Nike, Shell, and Texaco (Cruz, 2013). Therefore, actors need to work together to perform social responsibility. Unlike the classical social responsibility perspective, which is “charity” oriented, the newer perspective claims that social responsibility is an incentive for actors in the supply chain to act together to create additional revenue and benefits (Caruana and Chatzidakis, 2013). Besides, the newer perspective can only exist by involving consumers in the supply chain as the key to social responsibility. The different motivations among corporations and consumers in the supply chain for performing social responsibility are that the corporation consumes resources to produce and transport products whereas the consumer is responsible because of he or she consumes the products, which could damage the environment, society, or both after their consumption period (Hsueh, 2014).

Over the last 50 years, social responsibility in the supply chain has been transformed from single-corporation to multi-corporation involvement (Maloni and Brown, 2006). The empirical data show that social responsibility in the supply chain can be divided into five main streams (Ciliberti et al., 2008b); one of them is RLSR, which is related to source reduction, recycling, substitution, reuse, and disposal of materials.

Since the actors in the supply chain need to work together to balance the share of risk and profit, the impact on the supply chain performance of the role played by each social-responsibility-impacted actor in the supply chain must be carefully considered. Examples of roles played include (Cruz, 2013; Georgiadis and Besiou, 2008) the supplier as the resources social license holder; the manufacturer as the center of social responsibility cost–benefit receiver; the distributor as the promoter of social responsibility to the end customer; customers as the key to the success of the supply chain social responsibility; and legislators as the producers of social responsibility legislation. Because the focus is on gaining the involvement of a number of social-responsibility-impacted actors, it is not preferable to combine any streams, since this would increase the complexity of the activity but not the number of actors; for example, Purchasing Social Responsibility is done by the supplier-manufacturer (Carter and Jennings, 2002), where both actors are already involved in RLSR. Thus, RLSR is preferred because it involves a greater number of impacted actors compared to the other streams.

A comparison of the RLSR SD model features under this study and in previous research: Georgiadis et al. (2006), Vlachos et al. (2007), Georgiadis and Besiou (2008), Hsueh and Chang (2008), Georgiadis (2013), Georgiadis and Athanasiou (2013), and Sudarto et al. (2014), is presented in Table 1. The number of research articles on social responsibility issues is relatively limited (Govindan et al., 2014; Hsueh, 2015), especially in CLSCs. Therefore, the selected papers in Table 1 for selecting the benchmark model in this paper are based on the research articles most similar to the research in this paper that, to the best of the authors' knowledge, can be found.

As shown in Table 1, except for Hsueh and Chang (2008), the benchmark models have at least two fundamental similarities. First,

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