[Makara Journal of Technology](https://scholarhub.ui.ac.id/mjt)

Volume 27 | Issue 2 Article 5

8-31-2023

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Recommended Citation

Sudarto, Sumarsono; Takahashi, Katsuhiko; and Dewo, Mochammad (2023) "Challenges in Optimization for the Performance on Sustainability Dimensions in Reverse Logistics Social Responsibility," *Makara Journal of Technology*: Vol. 27: Iss. 2, Article 5.
DOI: 10.7454/mst.v27i2.1445
Available at: https://scholarhub.ui.ac.id/mjt/vol27/iss2/5

Makara J. Technol. 27/2 (2023), 75–80
doi: 10.7454/mst.v27i2.1445

Challenges in Optimization for the Performance on Sustainability Dimensions in Reverse Logistics Social Responsibility

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Abstract

Reverse logistics social responsibility is preferred as the most acceptable solution for addressing the challenges in stakeholders' debate regarding social responsibility in supply chains because it involves as many actors as possible in the supply chain to perform social responsibility to achieve sustainability. This paper explores the challenges in achieving optimal policies in sustainability dimensions for collection and recycling facilities in reverse logistics. Sustainability dimensions include economic, environmental, and social aspects. The reverse logistics is modeled on System Dynamics, and a simplified statistical analysis using a contour chart is employed in numerical experiments. Results show a narrow area of optimal solutions in contour charts for policy parameter settings to realize sustainability. Therefore, this paper finds that optimization of reverse logistics to develop sustainability is a highly challenging task for policy makers. Therefore, managers must carefully study their policies before implementation to avoid unnecessary and less optimal performance in the sustainability dimensions.

Keywords: *reverse logistics social responsibility, social responsibility in supply chain, sustainability dimensions, system dynamics (SD)*

1. Introduction

The importance of integrating corporate social responsibility (CSR) in supply chains to develop sustainability across organized related materials and information flows due to high pressure from stakeholders has been growing [1]. The requirement of stakeholders is accompanied by the following two barriers: the value of CSR for money doubt [3] and the investment source of CSR [14]. Both barriers generally argue that the economic return of CSR has not been demonstrated; therefore, no source of investment could be allocated. This problem has been addressed by [13, 16] when considering premium prices to investigate the economic return on the environmental and social dimensions of sustainability.

Meanwhile, integrated CSR in supply chains mainly deals with risk (supply-side disruption, social risk, and demand risk uncertainty) and profit [4]. This perspective concludes that poor CSR performance of any player in supply chains may damage focal firm reputation (e.g., the case of McDonalds, Mitsubishi, Monsanto, Nestlé, Nike, Shell, and Texaco). Therefore, instead of satisfying the requirements of stakeholders, the most important role of integrated CSR in supply chains lies in creating social license for firms to establish sustainability [11] and preserving the most valuable aspect of firms, that is, reputation [12]. Therefore, reverse logistics social responsibility (RLSR) is preferred as the most acceptable solution for addressing challenges in stakeholders' debate regarding CSR in supply chains [16].

This study explores the challenges in achieving an optimal policy in sustainability dimensions for collection and recycling facilities in RLSR. The RLSR model in SD is used similar to [16]. The supply chain considers a single product with complete Triple Bottom Line (TBL) sustainability dimensions. A simplified statistical analysis using a contour chart is employed in the numerical experiments. The SD model and contour chart are used to present possible actual market responses to obtain comprehensive results of challenges in optimizing capacity planning policies in collection and recycling facilities.

Contour charts serve as invaluable tools, offering a graphical representation of the optimal parameter settings that can lead to the attainment of TBL sustainability dimensions. These contour charts are meticulously crafted by mapping parameter configurations against measured performance, a process facilitated using MINITAB software. Such visual representations not only provide a clear and intuitive means of understanding the complex relationship between parameters and sustainability performance but also offer distinct advantages over alternative methodologies in their capability to illustrate the interplay between variables and guide decision-making processes in pursuit of sustainable objectives.

The paper is organized into the following sections. Section 1 presents the introduction. Section 2 discusses the seminal works in capacity planning for RL and RLSR. Section 3 explains the research methods. Section 4 presents the results and discussion. Section 5 concludes this paper and presents possible future directions.

The research on sustainability dimensions in RL has been continuously growing in the last decade. [9] focused on environmental dimension in a single product without cost elements. [10] emphasized the economic dimension in a single product, considering product lifecycle with uncertainties, expansion and contraction capacity planning, and early-stage capacity planning. [19] concentrated on the economic dimension in a single product and considered limited product lifecycle and capacity planning for contraction. [8] focused on economic and environmental dimensions in a single product and considered environment and legislation designs. [6] highlighted the economic dimension in dual products and considered product lifecycle with uncertainties and capacity planning for expansion and contraction. [7] focused on the economic dimension in dual products and considered product lifecycle with uncertainties and preference, expansion and contraction in capacity planning, and early-stage versus flexible capacity planning.

RLSR research continued to expand. [16] focused on complete TBL sustainability dimensions in a single product and considered premium prices from [13]. [18] concentrated on the impact on complete TBL sustainability dimensions in a single product by considering demand-side disruption. [17] focused on efficient flexible capacity planning to establish complete TBL sustainability dimensions in a single product. The limitation lies in several possible real-world alternatives based on [17].

Table 1 shows a comparison between the features of this paper and those of the most related previous papers such as [10, 16–18]. This study highlights the more complete TBL dimensions compared with [10]. In contrast to [17], the advantages of omitting flexibility in capacity planning to address demand-side disruption are highlighted. Moreover, consistent with the paper’s objective of catering not only to engineers but also to policy makers, the need for comprehensive explanations, particularly for those not extensively trained in this specific area, is recognized. Readers are encouraged to refer to [17, 18] for in-depth tutorials on the design and implementation process.

Recent studies offer valuable insights into pertinent areas of research [21] and examine the dynamic implications of carbon pricing on reverse supply chain (RSC) systems, emphasizing the need for adaptability and cost-effective management [22]. Moreover, these studies systematically examine corporate social responsibility (CSR) disclosure and its impact on financial performance, focusing on the banking sector [23], and address the scope and implementation of CSR in Indonesia, emphasizing the legal and regulatory aspects to pertinent considerations in the present discourse.

Table 1. Comparison of Research Features in Reverse Logistics and Reverse Logistics Social Responsibility

References	Additional Methods	Focus	Tradeoff
Georgiadis *et al*., 2006 [10]	Taguchi Design	Eco.	Demand disruption
S. Sudarto *et al*., 2014 [16]	Descriptive Statistics	Eco.; Env.; Soc.	Social responsibility
S. Sudarto *et al.*, 2016 [18]	Taguchi Design	Eco.; Env.; Soc.	Social responsibility; Demand disruption
S. Sudarto *et al.*, 2017 [17]	Operations Research	Eco.; Env.; Soc.	Social responsibility; Demand disruption
Proposed	Contour Chart	Eco.; Env.; Soc.	Social responsibility

Abbreviations: Eco. = Economics; Env. = Environment; Soc. = Social

2. Methods

Figure 1 shows the methods used in this study. First, the SD model of RLSR is created similar to [16] using AnyLogic software, a versatile simulation modeling tool that offers the advantage of supporting multiple modeling paradigms, including system dynamics, discrete event, and agent-based modeling, making it a powerful choice for various simulation applications. The flexibility of this model and its diverse modeling capabilities enable users to tackle complex real-world problems and gain comprehensive insights into system behavior. Second, the model is validated. Third, the numerical experiment is set up and then run using the MINITAB software. Finally, the results are discussed to reveal the drawbacks of this paper.

The SD validation refers to [2, 15]. The following two main tests are used: 1) direct structure test, which includes structure confirmation test [8][19], parameter confirmation test [8, 13, 19], and dimensional consistency test using AnyLogic software; 2) extreme condition and behavior sensitivity tests. Figure 2 shows the basic SD model in this paper. Methods for setting the levels for the parameters are described in [17].

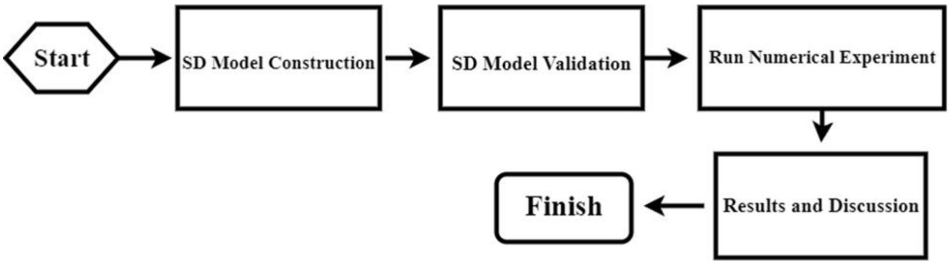

Figure 1. Flow Diagram of Methods

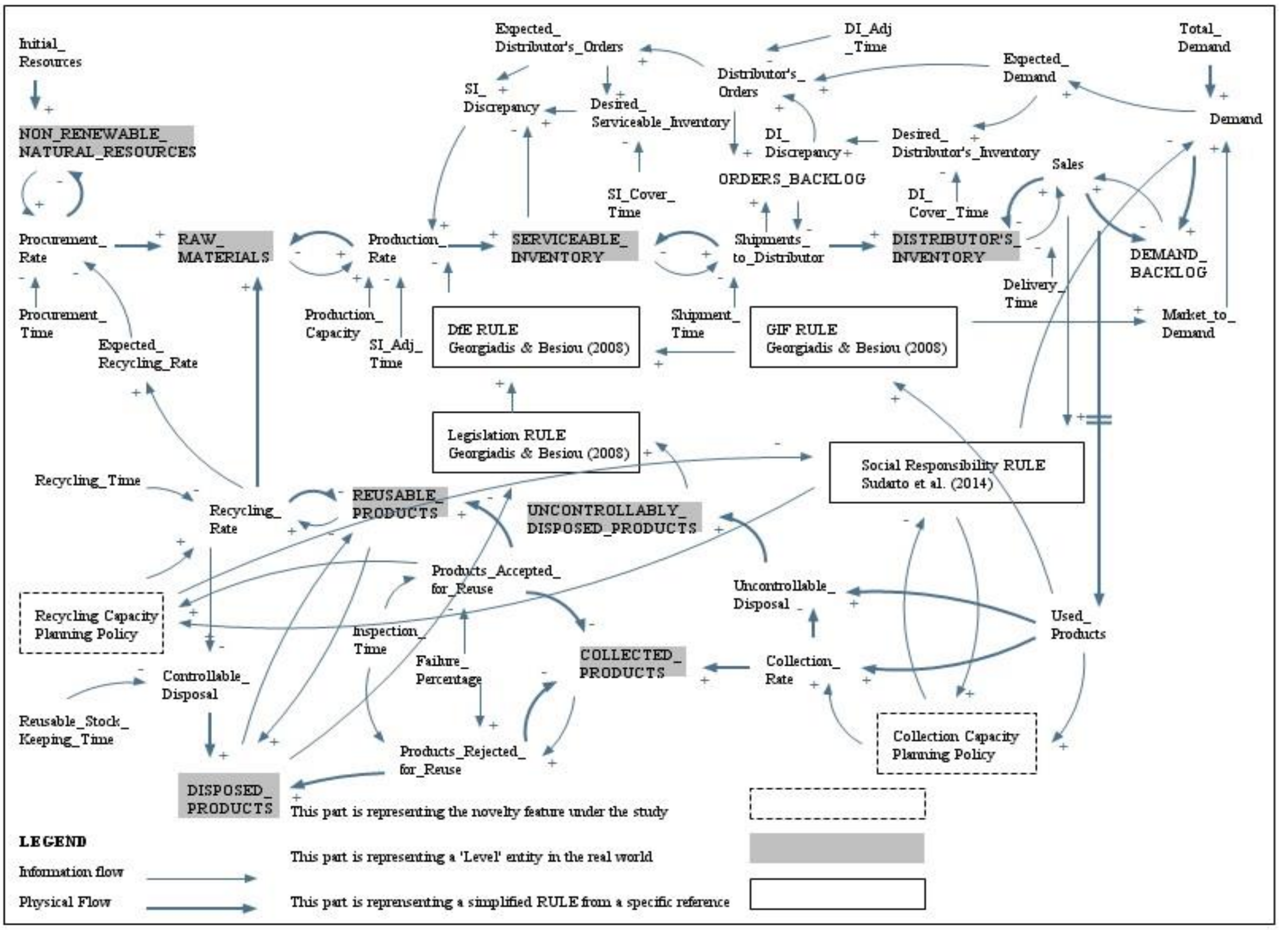

Figure 2. Causal Loop Diagram of Supply Chain with RLSR

3. Numerical Experiment

This study aims to find the optimal policy set for collection and recycling facilities in RLSR. The basic scenario with Legislation or L = {0.8, 0.75, 0} and Market Composition or MC = {0, 0, 0, 1} is the reference. The policy is then taken in Collection (Kc: Constant Number of Collection, Pc: Period of Collection), Recycling (Kr: Constant Numbers of Recycling, Pr: Period of Recycling), and CSR_Level as the social responsibility level in RLSR that creates premium prices (price hikes). The policy combination comprises the following:

a. Collection Facility
* Pc = 10, 50, 100, 150, 200, 250
Review Period of Collection for Capacity Expansion
* Kc = 0.5, 1, 1.5, 2, 2.5, 3
Constant Numbers of Collection for Capacity Expansion

b. Recycling Facility
* Pr = 10, 50, 100, 150, 200, 250
Review Period of Recycling for Capacity Expansion
* Kr = 0.5, 1, 1.5, 2, 2.5, 3
Constant Numbers of Recycling for Capacity Expansion

c. CSR_Level
* 0.2
* 0.3

The combination is simulated, and the measured performance is compared to determine the most suitable policy combination, producing 6 × 6 × 6 × 6 × 2 = 1944 combinations. Therefore, the experiment is created in a structured order similar to [14] to reduce the number of conducted experiments:

Kc–Kr and Pc–Pr at CSR_Level 0.2
Kc–Pc and Kr–Pr at CSR_Level 0.2
Kc–Kr and Pc–Pr at CSR_Level 0.3
Kc–Pc and Kr–Pr at CSR_Level 0.3

The optimal combinations of some samples of Kc, Kr, Pc, and Pr based on a, b, and c are selected. Thus, the number of experiments could be decreased from 1944 to 154, demonstrating a 92% reduction. A sensitivity analysis will be produced on the basis of their combinations of policy parameter settings. In this study, the final performance of the complete TBL dimensions is measured as follows: economic (Total_Supply_Chain_Profit), environmental (Green Image Factor–GIF), and social (Social_ Performance). Therefore, this performance is similar to [16–18].

4. Results and Discussion

Figures 3 to 8 show the results from numerical experiments. Figure 3 is the contour plot of impact to end of period in simulation results of measured performances by Kc–Kr at CSR_Level = 0.2–Economic. Figure 4 shows the contour plot of impact to end of period in simulation results of measured performances by Kc–Kr at CSR_Level = 0.2–Environment. Figure 5 is the contour plot of impact to end of period in simulation results of measured performances by Kc–Kr at CSR_Level = 0.2–Social. Figure 6 shows the contour plot of impact to end of period in simulation results of measured performances by Pr–Pc at CSR_Level = 0.2–Economic. Figure 7 is the contour plot of impact to end of period in simulation results of measured performances by Pr–Pc at CSR_Level = 0.2–Environment. Figure 8 is the contour plot of impact to end of period in simulation results of measured performances by Pr–Pc at CSR_Level = 0.2–Social.

Comparison of the results between Figures 3 to 5 and Figures 6 to 8 show that Kr–Kc provides wider optimal areas than Pr–Pc, demonstrating considerable differences

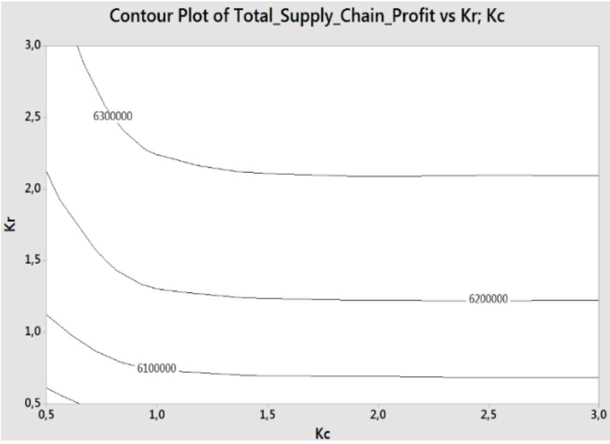

Figure 3. Contour Plot of Impact to End of Period in Simulation Results of Measured Performances by Kc–Kr at CSR_Level = 0.2–Economic

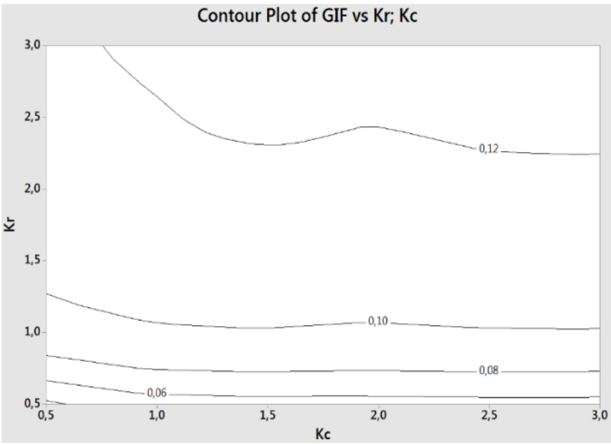

Figure 4. Contour Plot of Impact to End of Period in Simulation Results of Measured Performances by Kc–Kr at CSR_Level = 0.2–Environment

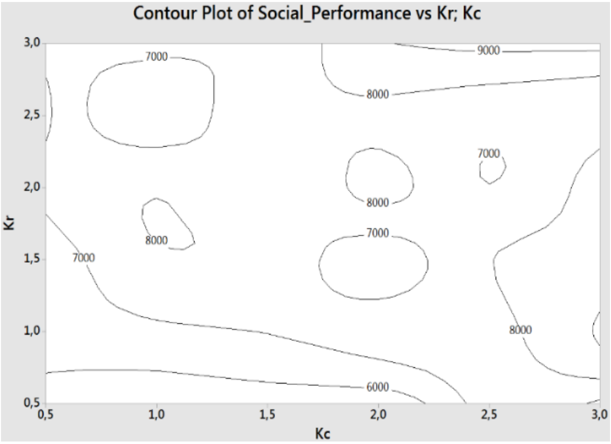

Figure 5. Contour Plot of Impact to End of Period in Simulation Results of Measured Performances by Kc–Kr at CSR_Level = 0.2–Social

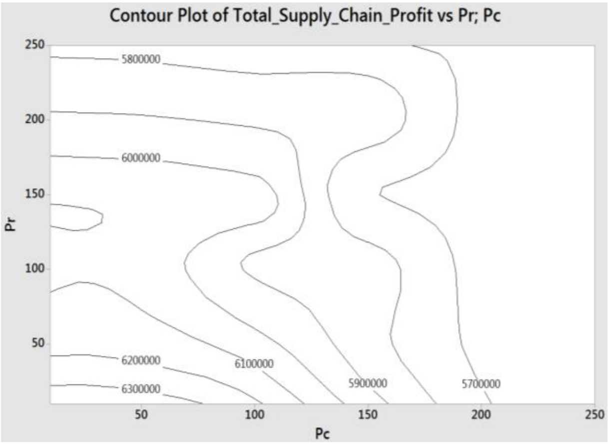

Figure 6. Contour Plot of Impact to End of Period in Simulation Results of Measured Performances by Pr–Pc at CSR_Level = 0.2–Economic

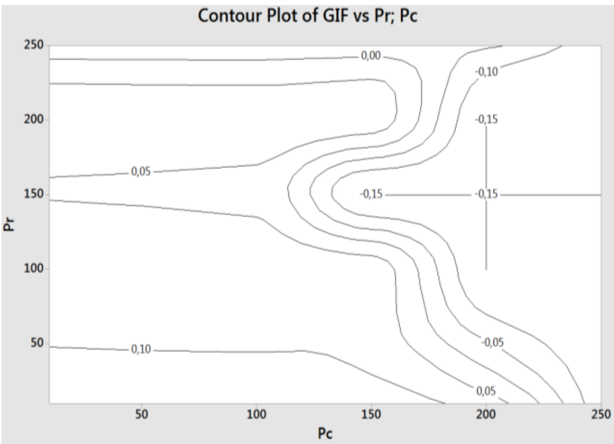

Figure 7. Contour Plot of Impact to End of Period in Simulation Results of Measured Performances by Pr–Pc at CSR_Level = 0.2–Environment

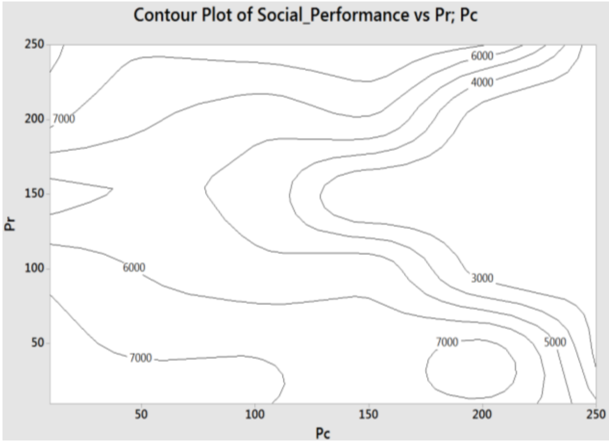

Figure 8. Contour Plot of Impact to End of Period in Simulation Results of Measured Performances by Pr–Pc at CSR_Level = 0.2–Social

in more than 100%. In addition, the optimal area is declining for Kr–Kc for the economic dimension compared to the environment and social dimensions. Meanwhile, the optimal area is also decreasing for Pr–Pc for the social dimension compared to the environmental and economic dimensions. This phenomenon is due to the review period (Pr–Pc), which causes a delay in spending money. By contrast, a constant (Kr–Kc) causes a fast time and a large amount of spending money. This insight is similar to [16], which only investigates optimality rather than exploring the challenges. However, the aforementioned phenomenon contrasts to [10, 17, 18] because they considered disruption. Therefore, any possible flexibility is also considered outside the optimality of sustainability dimensions.

5. Conclusions and Future Directions

This paper makes a notable contribution to the field of RLSR by tackling the challenge of optimization while considering the complete dimensions of TBL sustainability. The results reveal a limited optimal solution space within the contour chart using AnyLogic simulation software to model RLSR and employing contour chart analysis in MINITAB for numerical experiments. This finding poses a significant challenge for policymakers, who must exercise caution in parameter settings for collection and recycling facilities to achieve sustainability. This study also emphasizes the importance of thorough policy analysis before implementation to avoid suboptimal TBL performance.

The current study provides valuable insights for policymakers seeking to address the optimization challenge for sustainability. However, the real-world context is inevitably highly complex, with potential disruptions such as demand-side disruptions [18] and transportation disruptions [20]. Therefore, further research is essential, particularly in exploring the impact of disruptions on optimization considering RLSR. Additional research will help refine our understanding of these challenges and introduce highly effective solutions.

Acknowledgment

The first author owes special thanks to Hitachi Global Foundation, Japan, for grant ID HSF-S159. The authors are also grateful for Dr. Maria Besiou for her contribution in helping with the construction of the SD model in this study.

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