The Conceptual Framework of Information Technology Adoption Decision-making in a Closed-loop Supply Chain

Shu-San Gan[1]

[1]*Mechanical Engineering Department, Petra Christian University*
Jalan Siwalankerto 121-131 Surabaya, Indonesia
[1]gshusan@petra.ac.edu

***Abstract*— Closed-loop supply chain has gained a significant attention during the recent decades since there is an increased awareness toward sustainable development. However, the implementation of closed-loop supply chain is confronted with numerous barriers and challenges due to uncertainties in input as well as in process. In contrast to manufacturing process where the input is mostly homogeneous raw material, the reverse chain's input comes from product's end-of-use or end-of-life; therefore the timing, quality and quantity are uncertain. The recovery process also brings other challenges due to various quality grades of the product returns and various recovery options. On the other hand, information technology has been studied extensively in relation to supply chain management. Most of the works show that the use of information technology could enhance supply chain performance. However, the study on the importance of information technology in closed-loop supply chain is still limited. In this paper, we discuss the role of information technology and then propose a conceptual framework of decision making in adopting IT in closed-loop supply chain management. We propose a conceptual framework for IT adoption decision making with four essential key attributes that are evaluated for each of the closed-loop supply chain activities**

Keywords*— *information technology; closed-loop supply chain; framework; decision-making.

1. Introduction

In the recent decades, closed-loop supply chain (CLSC) has gained significant attention. The world has come to realize that there is a limitation to natural resources provided by our Mother Earth, and to the landfill for slow-decomposing materials. Government regulations are also playing an important role to the growth of CLSC. Many firms decided that closing the loop should not be a burden, but on the contrary, should bring tangible benefit (such as increased profit by market expansion, lower cost from using used-product rather than virgin material) or intangible benefit (such as green image, flexibility in the supply chain).

Closed-loop supply chain management is the process of designing, managing, and operating a system to achieve the optimal value creation from the point of origin of a product until its end of life with dynamic value recovery applied to various types and volumes of product returns [1]. Several literatures describe closed-loop supply chain as the integration of forward and reverse supply chain [2][3][4][5]. The focus of a CLSC should be on value creation over the entire product's life cycle.

However, the implementation of CLSC faces many challenges. Uncertainty is one of the prominent challenges. In the forward chain's manufacturing, the inputs which consist of raw materials and product parts, are homogeneous. On the contrary, the input of a remanufacturing process, which is product returns (or cores), are heterogeneous in quality, quantity, and timing [6]. These uncertainties can be a barrier in the implementation of a CLSC since it could increase the cost of reverse logistics – due to the variability in the timing of the product returns, the cost of recovery process – due to the variability in the quality of cores, and the economic production quantity – due to the variability in the quantity of product returns.

While facing such problem, it is observed that the use of Information Technology (IT) has increased considerably. There are many areas of supply chain management which are elevated by the use of IT, mostly in improving performance. The use of IT could be a significant determinants of supply chain relationship. Uncertainties in the different stages of the reverse supply chain can be reduced by the use of IT by enabling the accurate and timely information on the status, location, and condition of the product [7]. The intensity of IT connection between firms and their supplier supports logistics integration, which further supports the supply chain's performance [8]. In addition, IT implementation, in form of integration of logistics and cloud computing, would improve service quality, optimal planning, and reliable operations [9]. IT has revolutionized traditional supply chain such that the efficiency and responsiveness of a supply chain is improved [10].

Despite the plausible benefits, many decision makers believe they cannot afford to invest in IT implementation, but on the contrary even though the context is within the firm's policy, they cannot provide satisfactory justification for making the investment [11]. Therefore, it is important to explore the attributes in the decision making to adopt IT in CLSC, and put it in a structured way represented by a

International Journal of Supply Chain Management
IJSCM, ISSN: 2050-7399 (Online), 2051-3771 (Print)

framework, such that firms can consider the possibility of IT adoption in a comprehensive manner. Furthermore, there are very limited works that study the implementation of IT in a closed-loop supply chain with some different challenges as in a forward supply chain. This study discusses the role of information technology and then a conceptual framework of decision making in adopting IT in closed-loop supply chain management is proposed.

2. Closed-Loop Supply Chain

A closed-loop supply chain can be illustrated as in Figure 1 [12]. There are two main responsibilities of a closed-loop supply chain, i.e. to make sure the value-added processes according to customers' demands, and to collect product returns from customers with highest accountability [13].

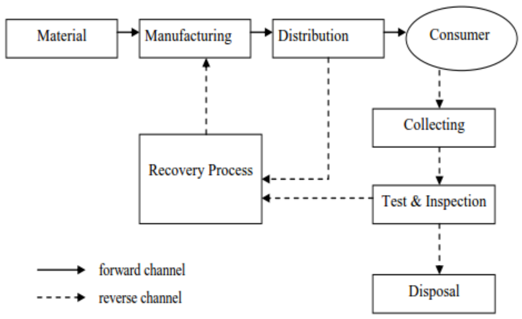

Figure 1. An illustration of closed-loop supply chain

There are several activities involved in the reverse channel i.e. (1) cores acquisition: collecting used products, (2) reverse logistics: transporting to recovery facilities, (3) product disposition: performing inspection and making disposition decision based on cores quality, product configuration, and other factors, (4) remanufacturing/reconditioning: capturing values from cores for reuse and resale, (5) remarketing: introducing the remanufactured/ reconditioned products to the market. The notable difference of a CLSC to a traditional forward supply chain is the management of product returns or acquisition. There are two focuses on product return, i.e.

- Type of returns which consists of: (a) Commercial returns: comes from consumer returns within a certain period after purchase, they are barely been used, and should be brought back to the market as soon as possible, (b) End-of-use returns: comes from functional products that are no longer desirable to the customers when technology upgrade is in place, (c) End-of-life returns: when products have reached their technical obsolete, or the users consider them to have lower utility than expected [14],

- Collection options which are (a) OEM collects the cores, (b) retailer collects the cores, under an incentive-scheme, and (c) third party is sub-contracted to collect used-products [15].

Reverse logistics is the process flow from the point of consumption to the point of origin which includes planning, executing, and managing raw material, in process inventory until finished goods as well as the related information, with the purpose of recapturing or creating value of appropriate disposal of used product [16]. After being transported to the recovery facilities, products are going through inspection, sorting, and disposition. The disposition alternatives are reuse, recovery (includes repairing, refurbishing, remanufacturing, cannibalization, and recycling), and disposal. Remanufacturing is one prominent recovery process which transform a used product into "like-new" product with similar warranty to the new one. The last activity is remarketing, where there are several issues that are different from marketing new product such as issues of developing market channels for recovered products, remarketing strategies, secondary markets, and dealing with cannibalization issues [13].

3. Information Technology Perspective in Closed-Loop Supply Chain

Digital technologies play an important role in supporting the transition to a circular economy. There are three applications i.e. (1) data collection, such as the use of Radio Frequency Identification (RFID), Internet of Things (IoT) using sensors and actuators, (2) Data integration, such as Relational Database Management Systems (RDBMS), Database Handling Systems, and Product Lifecycle Management (PLM) systems, and (3) Data Analysis, as in using machine learning, or big data analytics [17].

The use of IT in CLSC activities are also found in previous studies. By using focused resource commitments to IT, the reverse logistics performance can be significantly elevated in terms of authorizing, tracking, and handling returns. A case study in a small scale recycling company has shown that IT helps the company to operate well, and speculated the higher need of IT when the company goes into a larger chain. Another use of IT, i.e. intelligent agent technology, could improve the reverse logistics' flexibility, information visibility, and efficiency of the reverse logistics management [18]. The use of RFID in warehouse operation can reduce the distribution cost,8 and in the reverse supply chain it could reduce the cost, increase the service and production quality, and reduce pollution as well as waste [19]. Also, a power shift from waste-driven system to market-driven is observed when RFID is implemented. In terms of investment decision, IT-level is important in remanufacturing investment decision making [20].

There are several previous works that focusing on the role of Information Technology in some areas involved in a closed-loop supply chain, among others are in circular economy [17], reverse logistics [18], and remanufacturing [19]. However, to the best of our knowledge, there has not been a study that encompasses the use of IT in all of the CLSC activities. In term of investment decision issues, Kafuku et al. has conducted a literature review and propose a conceptual framework for remanufacturing investment analysis, that include considerations in remanufacturing companies type and level of technology readiness; physical resources availability; and technical, business, and legislative information availability [20]. This previous study however is not focusing on the decision-making to adopt IT-based system, even though it shows the importance of information to support successful remanufacturing implementation due to the notorious uncertainty issues in remanufacturing. In this study, we consider the use of IT in all of the CLSC activities, and make use of this consideration as a decision-making attributes to adopt IT-based system in a closed-loop supply chain management.

4. Key Attributes and Conceptual Framework for IT Adoption Decision-Making

The most common approach for decision making is weighing the benefits, costs, and risks. Therefore, we use the basic attributes in Kahraman [21] i.e. tangible benefit, intangible benefit, policy, and resources, and identify each sub-attribute when implemented in closed-loop supply chain management.

- Tangible benefit: the use of RFID can reduce the cost of tracking and handling returns, reduce distribution cost [7], reduce sorting cost [22], and reduce recovery cost based on the products' information that could mitigate the uncertainties in quality of used product as raw material [22]. Internet of Things (IoT) has also played an important role in CLSC, because it could trace, sort, and analyze the product life cycle data for each individual item, which again could mitigate the uncertainties. The use of IT can also reduce overall cost through optimization of integrated procurement, production, product recovery, pricing, and strategy of return acquisition [23]. Data analysis can provide tangible benefits i.e. optimize reverse logistics cost based by analyzing product's tracking data, increase revenue by analyzing the product's remaining life [24], reduce recovery cost by analyzing the product's life cycle data to mitigate the uncertainties [23], and increase revenue by analyzing the proper market channel.

- Intangible benefit: the data collected from RFID, IoT, and other IT-equipment could also bring intangible benefit, such as increasing service and production quality [19], reducing pollution as well as waste [19], encouraging power shift from waste-driven system to market-driven [19], improving the reverse logistics' flexibility [18], and improving information visibility [18].

- Policy Issues: since the IT based system relies on IT-equipment, the inevitable risk is failing equipment such as RFID is unable to read data, or interfered by other frequencies. The rate of failure could be determined from historical data or equipment's specification, and it should be considered in IT adoption decision-making. IoT has significant benefits, but also comes with risk in term of data security. Since everything is connected through internet, the risk of system infiltration should be taken into account. The company's sustainability policy could support IT system adoption, because a PLM system could support the sustainability through a life cycle assessment.

- Resources: IT adoption should consider the resources involved in the system, which are equipment, system, human resources, and completion time. The investment made for purchasing the equipment, buying or setting up an IT-based system, training the workers, and time to complete the adoption process, should be considered.

Knowledge sharing is very important in a CLSC, because the shared knowledge of a product throughout its life cycle would influence the supply chain performance in terms of efficiency, quality, and speed of service, innovation, and environmental impact [25]. Data integration in IT-based system would support knowledge sharing, and in turn could improve the CLSC performance. The proposed conceptual framework of IT adoption decision-making in a CLSC is presented in Figure 2, where the key attributes and the sub-attributes are evaluated for each of the CLSC activities.

5. Conclusion

We propose a conceptual framework for IT adoption decision making for an IT-system, whether it is a system of data collection, data integration, or data analysis. There are four key attributes, namely tangible benefits, intangible benefits, policy issues, and resources; that are essential in IT adoption decision making. Those attributes are further broken down into several sub-attributes, which would be significant in deciding IT adoption. Furthermore, the attributes are evaluated for each of the closed-loop supply chain activities.

This study is focused on the framework, and can be extended to the decision making process by implementing the relevant method such as Analytic Hierarchy Process (AHP) and heuristic methods, which could be the future research focus. Also, the implementation of knowledge sharing to complement the decision making framework could improve the effectiveness. It is also another avenue of future research.

References

[1] V. D. R. J. Guide and L. N. Van Wassenhove, "Closed-Loop Supply Chains: An Introduction to the Feature Issue (Part 2)," *Prod. Oper. Manag.*, vol. 15, no. 4, pp. 471–472, 2006.

[2] B. Lebreton, "Strategic Closed-Loop Supply Chain Management," in *Lecture Notes in Economics and Mathematical Systems 586*, Springer Berlin Heidelberg, 2007, pp. 1–158.

[3] K. K. Pochampally, S. M. Gupta, and K. Govindan, "Metrics for performance measurement of a reverse/closed-loop supply chain," *Int. J. Bus.*

Perform. Supply Chain Model., vol. 1, no. 1, pp. 8–32, 2009.

[4] G. Kannan, P. Sasikumar, and K. Devika, "A genetic algorithm approach for solving a closed loop supply chain model: A case of battery recycling," *Appl. Math. Model.*, vol. 34, no. 3, pp. 655–670, 2010.

[5] M. E. Ferguson and G. C. Souza, *Closed-loop supply Chains - New Developments to Improve the Sustainability of Business Practices*. CRC Press, Taylor & Francis Group, 2010.

[6] G. C. Souza, "Remanufacturing in Closed-Loop Supply Chains," *Prod. Invent. Manag. J.*, vol. 45, no. 1, pp. 56–66, 2009.

[7] V. Jayaraman, A. D. Ross, and A. Agarwal, "Role of information technology and collaboration in reverse logistics supply chains," *Int. J. Logist. Res. Appl.*, vol. 11, no. 6, pp. 409–425, 2008.

[8] D. Prajogo and J. Olhager, "Supply chain integration and performance: The effects of long-term relationships, information technology and sharing, and logistics integration," *Int. J. Prod. Econ.*, vol. 135, no. 1, pp. 514–522, 2012.

[9] N. Subramanian, M. D. Abdulrahman, and X. Zhou, "Integration of logistics and cloud computing service providers: Cost and green benefits in the Chinese context," *Transp. Res. Part E Logist. Transp. Rev.*, vol. 74, pp. 81–93, 2015.

[10] A. Gunasekaran, N. Subramanian, and T. Papadopoulos, "Information technology for competitive advantage within logistics and supply chains: A review," *Transp. Res. Part E Logist. Transp. Rev.*, vol. 99, pp. 14–33, 2017.

[11] A. Gunasekaran, E. W. T. Ngai, and R. E. McGaughey, "Information technology and systems justification: A review for research and applications," *Eur. J. Oper. Res.*, vol. 173, no. 3, pp. 957–983, 2006.

[12] S.-S. Gan, "Closed-loop Supply Chain as an Agent of Sustainable Development," *J. Tek. Ind.*, vol. 17, no. 1, pp. 7–16, 2015.

[13] K. Govindan, P. C. Jha, and K. Garg, "Product recovery optimization in closed-loop supply chain to improve sustainability in manufacturing," *Int. J. Prod. Res.*, vol. 54, no. 5, pp. 1463–1486, 2016.

[14] V. D. R. J. Guide and L. N. Van Wassenhove, "The Evolution of Closed-Loop Supply Chain Research," *Oper. Res.*, vol. 57, no. 1, pp. 10–18, Jan. 2009.

[15] R. C. Savaskan and L. N. Van Wassenhove, "Reverse Channel Design: The Case of Competing Retailers," *Manage. Sci.*, vol. 52, no. 1, pp. 1–14, 2006.

[16] K. Govindan, H. Soleimani, and D. Kannan, "Reverse logistics and closed-loop supply chain: A comprehensive review to explore the future," *Eur. J. Oper. Res.*, vol. 240, no. 3, pp. 603–626, 2015.

[17] A. Pagoropoulos, D. C. A. Pigosso, and T. C. McAloone, "The Emergent Role of Digital Technologies in the Circular Economy: A Review," *Procedia CIRP*, vol. 64, pp. 19–24, 2017.

[18] P. S. Wadhwa and J. Madaan, "Intelligent Agent Technology for Reverse Logistics," *IFAC Proc. Vol.*, vol. 39, no. 3, pp. 215–220, 2006.

[19] W. Zhou and S. Piramuthu, "Remanufacturing with RFID item-level information: Optimization, waste reduction and quality improvement," *Int. J. Prod. Econ.*, vol. 145, no. 2, pp. 647–657, 2013.

[20] J. M. Kafuku, M. Z. M. Saman, S. M. D. Yusof, S. Sharif, and N. Zakuan, "Investment decision issues from remanufacturing system perspective: Literature review and further research," *Procedia CIRP*, vol. 26, pp. 589–594, 2015.

[21] C. Kahraman, N. Yasin Ateş, S. Çevik, M. Gülbay, and S. Ayça Erdoğan, "Hierarchical fuzzy TOPSIS model for selection among logistics information technologies," *J. Enterp. Inf. Manag.*, vol. 20, no. 2, pp. 143–168, 2007.

[22] B. Bras, *Design for remanufacturing processes*. Wiley, Hoboken, NJ, 2007.

[23] C. Fang, X. Liu, P. M. Pardalos, and J. Pei, "Optimization for a three-stage production system in the Internet of Things: procurement, production and product recovery, and acquisition," *Int. J. Adv. Manuf. Technol.*, vol. 83, no. 5–8, pp. 689–710, 2016.

[24] O. Ondemir and S. M. Gupta, "Quality management in product recovery using the Internet of Things: An optimization approach," *Comput. Ind.*, vol. 65, no. 3, pp. 491–504, 2014.

[25] S.-S. Gan, "Knowledge Sharing in Closed-Loop Supply Chain Management," *Int. J. Ind. Res. Appl. Eng.*, vol. 2, no. 1, pp. 1–7, 2017.

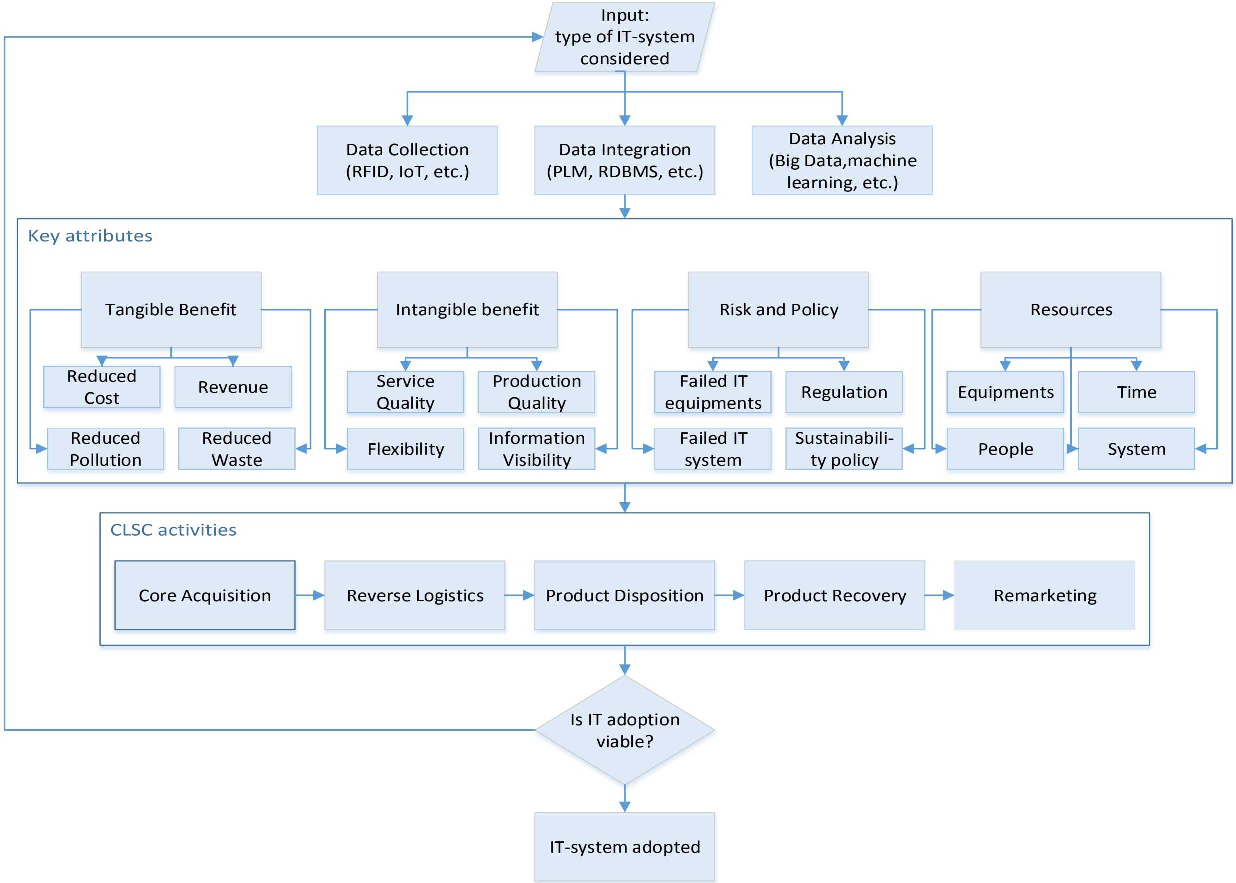

Figure 2. The proposed conceptual framework of IT adoption decision-making in a CLSC