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paper text:

The Conceptual Framework of Information Technology Adoption

Decision-making in a Closed-loop Supply Chain 4

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Received: …..Date……..? Accepted: ……..Date…….? 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 6

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 quality and quantity are 17

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 5
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 11
of

information technology and then propose a conceptual framework of decision making in adopting IT in

closed-loop supply chain management. Keywords: information **technology; closed-loop supply chain;** 10

framework; decision-making. 1.

Introduction In the recent decades, **closed-loop supply chain (CLSC) has** gained significant attention. **The** 8

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** 12

defined as "the design, control, and operation of a system to maximize value creation over the entire life cycle of a product with dynamic recovery of value from different types and volumes of returns over time".1 Several literatures describe

closed-loop supply chain as **the integration of forward** and reverse **supply chain.** 9

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** 14

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 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.7

Uncertainties in the different stages of the reverse supply chain 2

can be reduced by the use of IT by enabling the

accurate and timely information on the status, location, and condition of 2

the product.8 The intensity of IT connection between firms and their supplier supports logistics integration, which further supports the supply chain's performance.9 In addition, IT implementation, in form of

integration of logistics and cloud computing, would improve service quality, optimal planning, and 18

reliable operations.10 IT has revolutionized traditional supply chain such that the

efficiency and responsiveness of a supply chain is improved.11 Despite the 5

plausible benefits, many decision makers believes 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.12 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. 4

2. Closed-Loop Supply Chain A closed-loop supply chain can 7

be illustrated as in Figure 1.13 There are two main responsibilities

of a closed-loop supply chain, i.e. to make sure the 19

value-added processes according to customers' demands, and 20

to collect product returns from customers with highest accountability.14 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.15 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 1. 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.16 2. 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.17

Reverse logistics is defined as "....the process of planning, implementing and controlling the efficient, cost-effective flow of raw materials, in process inventory, finished goods and related information from the point of consumption to the point of origin for the purpose of recapturing or creating value or for proper disposal" 1

18. 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.19 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.14 3. Information Technology Perspective in Closed-Loop Supply Chain Digital technologies

play an important role in supporting **the transition to a** 15

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.20 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.21 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.22 Another use of IT, i.e. intelligent agent technology, could improve the reverse logistics' flexibility, information visibility, and efficiency of the reverse logistics management.23 The use of RFID in warehouse operation can reduce the distribution cost,8 and

in the reverse supply chain it could reduce **the** 22 cost, increase the service and production quality, and reduce pollution as well as waste.24 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.25 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, 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** 21

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 Kahraman26 i.e. tangible benefit, intangible benefit, policy, and resources, and identify each sub-attribute when implemented in

closed-loop supply chain management. **1.** Tangible benefit: **the** 6

use of RFID can reduce the cost of tracking and handling returns,21 reduce distribution cost,8 reduce sorting cost,27 and reduce recovery cost based on the products' information that could mitigate the uncertainties in quality of used product as raw material.27 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.** 3

The use of IT can also reduce overall cost through optimization of integrated

procurement, production, product recovery, pricing, and strategy of return acquisition. 3

28 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,29 reduce recovery cost by analyzing the product's life cycle data to mitigate the uncertainties,28 and increase revenue by analyzing the proper market channel. 2. Intangible benefit: the data collected from RFID, IoT, and other IT-equipment could also bring intangible benefit, such as increasing service and production quality,24 reducing pollution as well as waste,24 encouraging power shift from waste-driven system to market-driven,24 improving the reverse logistics' flexibility,23 and improving information visibility.23 3. 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. 4. 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** 13

performance in terms of efficiency, quality, speed of service, innovation, and environmental impact30. 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 In conclusion, this study discuss the role of information technology and then a conceptual framework of decision making in adopting IT in closed-loop supply chain management is proposed. There are four key attributes which are further broken down into several sub-attributes, which would be essential in deciding IT adoption. References 1. Guide, V.D.R. and Wassenhove, L.N.V., 2006. Production and Operations Management, 15(4), pp.471-472. 2. B. Lebreton. Lecture notes in economics and mathematical systems, Springer, Berlin (2007) 586 3. Pochampally et al., 2009; Pochampally, K.K., Gupta, S.M. and Govindan, K., 2009. International Journal of Business Performance and Supply Chain Modelling, 1(1), pp.8-32. 4. Kannan, G., Sasikumar, P. and Devika, K., 2010. Applied Mathematical Modelling, 34(3), pp.655-670. 5. Ferguson, M.E. and Souza, G.C., 2010. Closed-loop Supply Chains: New Developments to Improve the Sustainability of Business Practices, pp.1-6. 6. Souza, G.C., 2009. Production and Inventory Management Journal, 45(1), pp.56-66. 7. Subramani (2004) Subramani, M., 2004. Mis Quarterly, pp.45-73. 8. Jayaraman, V., Ross, A.D. and Agarwal, A., 2008. Int. J. Logist. Res. Appl., 11(6), pp.409-425. 9. Prajogo, D. and Olhager, J., 2012. International Journal of Production Economics, 135(1), pp.514-522. 10. Subramanian, N., Abdulrahman, M.D. and Zhou, X., 2014. Transp. Res. E Logist. Transp. Rev., 70, pp.86-98. 11. Gunasekaran, A., Subramanian, N. and Papadopoulos, T., 2017. Transp. Res. E Logist. Transp. Rev., 99, pp.14-33. 12. Gunasekaran, A., Ngai, E.W. and McGaughey R.E., 2006. Eur. J. Oper. Res., 173(3), pp.957-983. 13. Gan, S.S., 2015. Jurnal Teknik Industri, 17(1), pp.7-16. 14. Govindan, K., Jha, P.C. and Garg, K., 2016. International Journal of Production Research, 54(5), pp.1463-1486. 15. Guide, V.D.R. and Van Wassenhove, L.N., 2002. The reverse supply chain. Harvard Business Review. 16. Guide Jr, V.D.R. and Van Wassenhove, L.N., 2009. Operations research, 57(1), pp.10-18. 17. Savaskan, R.C., Bhattacharya, S. and Van Wassenhove, L.N., 2004. Management science, 50(2), pp.239-252. 18. Rogers, D.S. and Tibben-Lembke, R., 1999. Council of Logistics Management, p.2. 19. Thierry, M., Salomon, M., Van Nunen, J. and Van Wassenhove, L., 1995. California Man. Rev., 37(2), pp.114-135. 20. Pagoropoulos, A., Pigosso, D.C. and McAloone, T.C., 2017. Procedia CIRP, 64, pp.19-24. 21. Daugherty, P.J., Richey, R.G., Genchev, S.E. and Chen, H., 2005. Transp. Res. E Logist. Transp. Rev., 41(2), pp.77-92. 22. Dhanda, K.K. and Hill, R.P., 2005. International Journal of Technology Management, 31(1-2), pp.140-151. 23. Wadhwa, S. and Madaan, J., 2006. IFAC Proceedings Volumes, 39(3), pp.215-220. 24. Zhou, W. and Piramuthu, S., 2013. International Journal of Production Economics, 145(2), pp.647-657. 25. Kafuku, J.M., Saman, M.Z.M., Sharif, S. and Zakuan, N., 2015. Procedia CIRP, 26, pp.589-594. 26. Kahraman, C., Yasin Ateş, N., Çevik, S., Gülbay, M. and Ayça Erdoğan, S., 2007. Journal of Enterprise Information Management, 20(2), pp.143-168. 27. Bras, B., 2007. Design for remanufacturing processes (pp. 283-318). Wiley, Hoboken, NJ. 28. Fang, C., Liu, X., Pardalos, P.M. and Pei, J., 2016. Int J Adv Manuf Tech., 83(5-8), pp.689-710. 29. Ondemir, O. and Gupta, S.M., 2014. Computers in Industry, 65(3), pp.491-504. 30. Gan, S.S., 2017. International Journal of Industrial Research and Applied Engineering, 2(1), pp.1-7. Figure captions Figure 1. An illustration of closed-loop supply chain. Figure 2. The proposed conceptual framework of IT adoption decision-making in a CLSC. Figure 1. Gan, Shu-San Input: type of IT-system considered Data Collection (RFID, IoT, etc.) Data Integration (PLM, RDBMS, etc.) Data Analysis (Big Data,machine learning, etc.) Tangible Benefit Intangible benefit Risk and Policy Resources Reduced Cost Revenue Service Quality Reduced Pollution Reduced Waste Flexibility Production Quality Information Visibility Failed IT equipments Failed IT system Regulation Equipments Time Sustainabili- ty policy People System Core Acquisition Reverse Logistics Product Disposition Product Recovery Remarketing Is IT adoption viable? IT-system adopted Figure 2. Gan, Shu-San 1 2 3 4 5 6 7