Closed-loop Supply Chain with Remanufacturing: A Literature Review

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Abstract

In supporting environmental sustainability, managing product returns has become a very important and challenging issue. Responding to this trend, researchers in many parts of the world have conducted numerous studies in reverse logistics and reverse supply chain, that were considered separately from the forward channel of supply chains. Meanwhile, there are opportunities to create added values from product returns and to improve efficiency when both channels are considered in an integrated way, as a closed loop supply chain. On the other hand, remanufacturing is a very appealing option among product recovery processes that has potential to increase the value of product returns. However, the available literature and theories on closed loop supply chain with remanufacturing are still limited. This paper aims to provide a literature review that covers closed loop supply chain with remanufacturing to identify its characteristics based on previous works in this area. The review methodology is content analysis, classified into managerial aspects and technical aspects with their subsequent topics. Related literatures will be mapped under the abovementioned structures while identifying other important aspects that have potentials for further study. An outline of research opportunities will presented as a result of the review.

Keywords: closed-loop supply chain, remanufacturing, review, environmental regulation, profitability.

1. Introduction

In a competitive market, manufacturing companies are struggling to implement the most efficient way in fulfilling market demands. As the environmental issues emerged, there were compelling needs to respond to natural resources depletion and enormous waste that went to landfill as well as water and air pollution.. Decade of 1970s was the beginning of environmental law system in the US, represented by Environment Protection Agency (EPA) that initially brought up regulations on the amount of pollution or waste that industry can put into the environment [1]. However, these regulations had been viewed as a burden adding up to already complex manufacturing processes. Extended Producer Responsibility (EPR) is an environmental policy in which a producer's responsibility for a product is extended to the post-consumer stage, promoted by OECD (Organization for Economic Co-operation and Development) since 1984. The increased emphasis on environmental issues has encouraged companies to develop various decision models that help complying with regulations while maintaining profitability. (cited from Pandey et al., 2007) [2]. In Europe, the most influencing regulation is Waste Electrical and Electronics Equipment Directive (WEEE) which was adopted in 2003. This directive has stimulated reverse chain activities within a supply chain [3]. Take back activities followed by recovery processes can also result in business profitability. As an example, remanufacturing return products could reduce the production cost compared to producing new products (in terms of less new material and less manufacturing processes required) while reducing the environment cost at the same time [4]. Clearly, there is a need to consider the supply chain, not only on the forward channel but also the reverse channel that dealing with returned products, which bring us to the importance of closed-loop supply chain.

There has been a number of attempt to review literature on reverse logistics (RL). Fleischmann [5] discussed dimensions of the RL, namely motivation for reuse, type of items recovered, form of reuse, and actors involved. de Brito [6] described and discussed cases of RL in practice and Pokharel [7] showed that researches in RL has been increasing significantly since 2005 and used content analysis method to show a holistic perspective from input and collection, structure, process and output. In the area of Reverse Supply Chain (RSC), Prahinski [8] organized RSC sequentially by five key steps: product acquisition, reverse logistics, inspection and disposition, reconditioning, and distribution and sales (cited from Guide, 2002), and proposed 10 empirical research propositions.

Despite the numerous works on closed-loop supply chain in the last decade, a literature review on closed-loop supply chain has not yet been done. In this paper, we will provide a review that covers closed-loop supply chain focused on remanufacturing as the recovery process, and an outline of research opportunities will be presented as a result of the review

2. Definition

2.1 Closed-loop Supply Chain

Closed-loop supply chain (CLSC) management is 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*" [9]. This definition has been evolved from merely integration of forward and reverse channel of supply chain

2.2 Remanufacturing

"Remanufacturing is the process of restoring a non-functional, discarded, or traded-in product to like-new condition" [10]. From the producers point of view, "like-new condition" represents the intention and ability to perform process to produce such result. On the other hand, from customer point of view, it represents their expectation toward the remanufactured products. Remanufacturing has existed in the United States for at least a century. For example, remanufacturing of electric motors was already started in the beginning of 20th century although it did not bear the name at that time [10].

3. Methodology of the Review

There are various approaches in performing a literature review. We use content analysis which is quite representative and commonly used. Again, there are several theories on content analysis, but we selected the most suitable for our purposes. According to Michael Palmquist, a conceptual analysis is conducted for establishing the existence and frequency of concepts in a text (in our case, "in a set of articles"), and may be followed by a relational analysis which is examining the relationships among concepts.

The first step is collecting articles from online journal databases, namely Science Direct, ProQuest, and Emerald. Two sets of search-keywords were applied to the predefined databases, which were "closed-loop supply chain" in (TITLE, ABSTRACT,KEYWORD/TAGS); AND "remanufacturing" in all fields. The search was limited to journal articles, excluding books and conference proceedings, as well as journals with "In Press – corrected proof" status. This process has resulted in 56 journal articles from ScienceDirect, 24 from ProQuest and 8 from Emerald. Some articles appeared in more than one databases. The articles were then checked for relevance to the topic discussed in this study. Some papers only used the term "closed-loop supply chain" as a representation to the comprehensive idea of the system while issues discussed were only focused on the reverse flows. In this case, the articles were excluded because the main interest of this study is the integration of forward and reverse supply chain, and both chains should be considered simultaneously. Table 1 shows a list of publications selected from this process and the frequency of relevant articles appeared in the publications. The next step is reorganizing articles to identify the various concepts. A brief remark about "who said what" and "to what extent and with what effect" is presented for each article. Finally, a mapping is performed by identifying the content genre, making a list of the concepts and synthesizing them to develop an outline of research opportunities.

Table 1: List of Journals and article appearance frequency

No	Name of Publications (Journals)	Freq
1.	*Advanced Engineering Informatics*	1
2.	*Applied Mathematical Modelling*	2
3.	*Asia Pacific Journal of Marketing and Logistics*	1
4.	*CIRP Journal of Manufacturing Science and Technology*	1
5.	*Computers & Chemical Engineering*	1
6.	*Computers & Industrial Engineering*	1
7.	*Computers & Operations Research*	3
8.	*Energy Procedia*	1
9.	*European Journal of Operational Research*	7
10.	*Expert Systems with Applications*	2
11.	*Fuzzy Sets and Systems*	1
12.	*Interfaces*	3
13.	*International Journal of Production Economics*	5
14.	*Journal of Cleaner Production*	2
15.	*Journal of Environmental Management*	1
16.	*Journal of Managerial Issues*	1
17.	*Journal of Manufacturing Technology Management*	2
18.	*Journal of Operations Management*	2
19.	*Mathematical and Computer Modelling*	2
20.	*Operations Research*	1
21.	*OR Spectrum*	2
22.	*Production and Inventory Management Journal*	2
23.	*Production and Operations Management*	5
24.	*Resources, Conservation & Recycling*	2
25.	*Supply Chain Management: An International Journal*	3
26.	*Technovation*	1
27.	*The International Journal of Logistics Management*	2
28.	*Transportation Research Part E*	4

4. Structure of the Review

The earliest paper within the searching scope is Fleischmann's [11] in which a recovery network design model was proposed and applied to copier remanufacturing and paper recycling to illustrate the model and investigate the impacts of different return rates on the network design. The study showed that product recovery can be implemented without major changes in the existing forward production and distribution networks, and that forward and reverse networks can be modeled separately

In 2003, a special section with closed loop supply chain issues were discussed in *Interfaces* edited by Guide & Wassenhove [12]. In contrast to Fleischmann's finding, an overview paper by Guide et al. [13] argued that closed-loop supply chains differ significantly from forward supply chains in many aspects, and not yet well understood. Also, the various types of product returns have made the problems more complicated. Meanwhile, there is an interest growth on closed-loop supply chain in the US for the potential profitability and in the European Union because of legislation. Therefore, several future research challenges were presented in the paper.

Flapper [14] gave an introduction to feature cluster on closed loop supply chains in European Journal of Operational Research volume 191, where three important issues were addressed, namely strategic decision in product design and returns processes, collection aspect of CLSC, and sharing resources for production and remanufacturing

Kleindorfer et al. [15] reviewed first 50 issues of *Production and Operations Management* journal, focused on sustainable operations management themes, namely green-product design, lean and green operations, and closed-loop supply chains, found that CLSC foster sustainability. Guide & Wassenhove [9] [16] introduced the feature issue on closed loop supply chains in journal of *Production and Operation Management*, volume 15, issues number 3 and 4. They stated that there are numerous, unresolved managerially relevant issues in CLSC that need further investigation. Also, interdisciplinary and industry-driven studies were encouraged.

Iglin & Gupta [17] presented a rigorous state-of-the-art review on environmentally conscious manufacturing and product recovery (ECMPRO) and concluded that Reverse Logistics (RL) literature is dominated by the studies on location-allocation models, and remanufacturing systems are often analyzed by considering only one specific operations management issue such as inventory management or production planning

The subsequent articles are then reorganized and classified under two main aspects, namely "managerial aspects", and "technical aspect". A detailed structure is given in Figure 1.

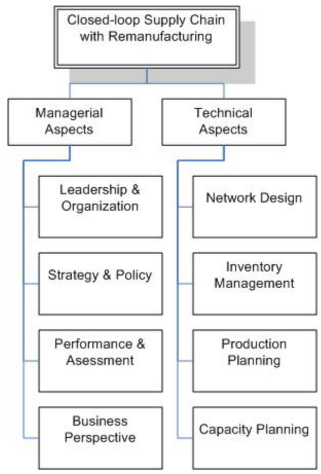

Fig. 1 The Structure of CLSC Literature Review

5. Managerial Aspect

Conceptual and research papers addressing the managerial aspect of CLSC are classified into four topics as depicted in figure 1. Strategy and policy issues dominated the articles within this category, while Leadership and organization was the least discussed topic. Guide & Wassenhove [13] [9] [18] have consistently promoted the importance of business perspective to make CLSC attractive to managers and decision makers, and focused on profitable value recovery from returned products, but only a few research focused on business perspective found. On the other hand, performance and assessment on CLSC has been a growing issue in this recent year.

5.1 Leadership and Organization

Defee et al. [19] proposed the development of closed-loop supply chain orientation (CLSCO) as a strategic alternative for competitive advantage, and its adoption may be enhanced when the supply chain leader demonstrates a transformational leadership style in the presence of socially important environmental issues. The existence of CLSCO would increase the CLSC capabilities and allows CLSC management as a source of competitive advantage.

5.2 Strategy and Policy

Successful implementation of closed-loop supply chain should be started with the right motives and drivers. The most recognized motives are increased profitability and regulation compliance. Hammond & Beullens [3] studied closed-loop supply chain network equilibrium under legislation, and found that such legislation could stimulate reverse chain activities. However, Seitz's critical assessment of motives for product recovery in the case of engine remanufacturing, based on in depth interviews, has revealed that ethical/moral responsibility, legislation and direct profitability had low degree of influence to induce remanufacturing, and instead, secure spare parts supply, source of warranty, market share and brand protection showed to be the most influencing factors [20]. Accordingly, Guide & Wassenhove [18] concluded that minimizing the costs of returns is not always the right perspective, there are different types of returns over the life cycle, and products have different time sensitivities, therefore it is necessary to maximize value over the entire product life cycle to gain the economics benefit.

Some efforts were done to identify the strategies to implement CLSC. Guide et al. [21] takes a contingency approach to explore the factors that impact production planning and control for closed-loop supply chains with product recovery, and three cases representing Remanufacture-to-Stock (RMTS), Reassemble-to-Order (RATO), and Remanufacture-to-Order (RMTO) were examined. Talbot et al. [22] conducted an empirical study on environmentally responsive SME's to investigate strategies to increase the residual value of the products at the end of products' useful life. Kumar & Putnam [23] studied reverse logistics strategies and primary forces to close the supply chain in the product life cycle. It was carried out for three sectors which are automotive, consumer appliances and electronics. Also, Zhu et al. [24] reported results from surveys with manufacturers in four typical Chinese industries, which are power generating, chemical/petroleum, electrical/electronic and automobile. The survey was conducted to study the implication of adopting Green Supply Chain Management and implementation of Closed-loop Supply Chains practices. In the activities involving remanufacturing, Souza [25] discussed key characteristics that distinguish remanufacturing from regular manufacturing and describe remanufacturing practices in four industries: cell phones, auto- motive engines, cartridges, and computer networking equipment. Recently, Grant & Banomyong [26] employed a case study approach with in-depth interviews and structured observation of Product Recovery Management (PRM) processes and found that efficient and effective product recovery and recycle manufacturing system can be designed by standardizing high-quality raw materials, using a modular structure for the product and maintaining control over the entire process and bypassing the temptation to use third-party collectors and processors. Extending the forward chain, Wikner & Tang [27] argued that the conventional concept of the customer order decoupling point (CODP) framework for forward flow supply chains can be extended to cover reverse material flows.

Partnership posed as one among other strategies to improve the CLSC performance. Kumar & Malegeant [28] investigated the strategic alliance in a closed-loop supply chain, in a case of manufacturer and eco-non-profit organization. The importance of CLSC relationships for remanufacturing was investigated by Ostlin [29], and identified ownership-based, service- contract, direct-order, deposit-based, credit-based, buy-back and voluntary-based relationships, and furthermore built theory around these different relationships. Another interesting insight was presented by Chen & Chang recently, that investigates the conditions for an OEM to take cooperative approach by participating in remanufacturing, or competitive approach by letting third party to remanufacture and market product returns as a competition to new products. [30].

When a competitive approach is chosen, it is important to recognized strategies related to it. Webster & Mitra [31] studied the competitive strategy in remanufacturing and the impact of take-back laws, while in the subsequent year, Mitra & Webster [32] addressed the competition in remanufacturing and the effects of government subsidies.

Implementation of CLSC with remanufacturing comes with additional complexity in terms of increased uncertainty in product returns and rate of remanufacturability. Ketzenberg et al. [33] explored the Value of Information (VOI) to reduce the effect of uncertainty with respect to demand, returns and product recovery. Also the Value of Partial Information (VOPI) and Value of Full Information (VOFI) were studied. Extending the previous work, Ketzenberg [34] investigated the value of information in capacitated closed loop supply chain when multiple sources of uncertainty exist, which are demand, returns, recovery yield, and capacity utilization. Visich [35] proposed that RFID can be effectively used to help decision making during the return process and to enhance value recovery. As the RFID system cost decreases and standards become clearer, it has become a promising tools to provide solutions in managing product returns across the entire supply chain.

The closed loop supply chain system behavior was studied by Georgiadis & Besiou [36] using system dynamic approach for sustainability in electrical and electronic equipment closed-loop supply chains. Kumar & Yamaoka [37] also applied system dynamics approach to study the behavior of closed loop supply chain system for the Japanese automotive industry. Winkler [38] recommended the establishment of closed-loop production systems in a supply chain level by introducing the concept of sustainable supply chain networks (SSCN). A SSCN features economic and environmental activities and companies stand to gain both economical and environmental benefit.

Guide & Wassenhove [18] presented the Evolution of Closed-Loop Supply Chain Research, and divided the evolution into five phases, namely the golden age of remanufacturing, from remanufacturing to valuing the reverse-logistics process, coordinating the reverse supply chain, closing the loop, and prices and markets. The authors argued that CLSC research has shifted from individual activities in the reverse supply chain to interdisciplinary research with marketing and accounting.

5.3 Performance & Assessment

A performance evaluation system is important for achieving a successful closed-loop supply chain, as well as the tools to measure it. Olugu & Wong [39] proposed an expert fuzzy rule-based system for closed-loop supply chain performance assessment in the automotive industry. Paksoy et al. [40] proposed operational and environmental performance measures in a multi-product closed-loop supply chain, while Mondragon et al. [41] provided measures for auditing performance and integration in closed-loop supply chains. Iglin & Gupta [42] proposed the implementation of Sensor embedded products (SEPs) to improve reverse or closed loop supply chain system performance, related to high level of uncertainty associated with the disassembly yield due to non-functional and/or missing components.

5.4 Business Perspective

Profitability can not be excluded in closed loop supply chain implementation, for it to be accepted by industry. Therefore, a business perspective is in place to be discussed under the CLSC area. The first concept was presented by Guide & Wassenhove [13] where a number of reasons to the need of new business models were presented. Companies need to develop business models that are different from the forward chain, and incorporated the various types of returns along the product life cycle, furthermore it is also possible for industries to replace product ownership with creative service offerings. Wells & Seitz [43] also proposed business models and a typology of closed-loop supply chain, where business model should be redesigned and placed closed loop systems at the heart of it rather than as an accessory that must be adapted to the demands of existing approaches. In terms of pricing, Wei & Zhao [44] proposed an optimal pricing decision problem of a fuzzy closed-loop supply chain with retail competition, where the fuzziness is associated with customer demands, remanufacturing cost, and collecting cost. Also, Huang et al. [45] proposed a quantity discount contract approach to deal with large proportion of false failure returns and presented explicit forms of such contracts for different assumptions about the distribution of the number of returns.

6. Technical Aspect

On the implementation stage of CLSC, it is important to explore the technical aspects. The most frequent topic found in this aspect is CLSC network design, that has been discussed under different focuses, but studies on inventory management, production planning and capacity planning are limited.

6.1 Network Design

Most of the works on CLSC network design were aimed at finding the optimum network in terms of location allocation problems. Schultmann et al. [46] develop a model for reverse logistic tasks by means of vehicle routing planning, within closed-loop supply chains and took an example from the automotive industry. Min et al. [47] studied the spatial and temporal consolidation of returned products in a closed-loop supply chain network using Genetic Algorithm, to address the bottlenecks on the collection points. Yang et al. [48] discussed the optimization of the closed-loop supply chain network by developing a model of general CLSC network consists of raw material suppliers, manufacturers, retailers, consumers and recovery centers. The equilibrium state of the network was optimized by using the theory of variational inequality.

Salema et al. [49] proposed a strategic location-allocation model, as well as a tactical model for closed-loop supply chains that includes production, storage and distribution planning. Pishvaee et al. [50] proposed a model for integrated logistics network design to avoid the sub-optimality caused by a separate, sequential design of forward and reverse logistics networks. This is a bi-objective model that minimize costs and maximize supply chain responsiveness, and were applying multi-objective memetic algorithm (MOMA) for the solution of model The result was then compared to the solution using multi-objective genetic algorithm(MOGA), and showed that solution using MOMA outperformed the one using MOGA.

Managing product returns involves many levels of uncertainty, mostly in quantity and quality of product returns and the rate of remanufacturability. To cope with this issue, several works on network design were developed under uncertainty condition. Amaro & Povoa [51] studied the effect of uncertainty on the optimal closed-loop supply chain planning under different partnerships structure. Pishvaee & Torabi [52] applied a possibilistic programming approach for closed-loop supply chain network design under uncertainty, which was compared to the previous work using MOMA. Pishvaee et al. [53] proposed a robust optimization approach to closed-loop supply chain network design, for handling the inherent uncertainty of input data in a closed-loop supply chain network design problem. Yingfei et al. [54] was applying the cooperative game model to get an income allocation scheme that maintains a stable coalition. Since the classical Shapley values suffered from unreasonably high uncertainty, the paper modified Shapley value to solve the allocation problem of CLSC under Third-Party Reclaim.

Some frameworks were also presented. For a simultaneous design and planning of supply chains with reverse flow, Salema et al. [55] proposed a generic modeling framework and then applied the graph approach. In order to validate the applicability and adequacy of the model, a case is studied. Krikke [56] also develop a decision framework for optimizing closed loop network configuration on carbon footprints, and use copiers as the study case.

Wang & Hsu [57] emphasized the difference between prolonged supply chain and CLSC, and then developed a closed-loop logistic model for decisions of facility locations and material flows through a capacitated CLSC with minimum total cost. The solution was obtained by means of a spanning-tree based genetic algorithm.

Stretching back to the product design activity, Das & Chowdhury [58] proposed a reverse logistics network for optimal collection, recovery and quality-based product-mix planning with modular product design. The proposed modular product design approach would create a design criterion that provides an improved recovery process at a lower cost.

6.2 Inventory Management

The discussion on CLSC inventory management started with a real case of leading company that has recognized the benefit of CLSC. Fleischmann et al. [59] developed an inventory model for IBM's dismantling source in spare-part management, and included elements that reflect the interaction between the dismantling channel and the existing new-buy channel and repair channel. As a result, IBM was recommended to make use of all dismantling opportunities as long as it had any uncovered demand.

Addressing bullwhip effects that are commonly found on forward supply chain, Zhou & Disney [60] studied how a remanufacturing process affects traditional pipelines in terms of the bullwhip phenomena and concluded that returned product can be used to reduce the inventory variance and bullwhip effect compared to manufacturer without remanufacturing or reverse logistics.

An optimal policy for a closed-loop supply chain inventory system with remanufacturing was proposed by Chung et al. [61], showed that integrated centralized decision making significantly increases the joint profit of supplier, manufacturer, third party collector and retailer under contractual design, compared to decentralized one. Yang et al. [62] extended the model by considering out of date as a type of deterioration and the findings still confirmed that integrated decisions jointly made by all involved parties in the supply chain could significantly increase the joint profit. In contrast, Lee et al. [63] presented a model that integrates pricing, production, and inventory decisions in a decentralized reverse production system (RPS) with retailer collection, and under Stackelberg game, where the manufacturer acts as leader and retailer as follower. Key parameters for determining the conditions under which the firms can obtain lower optimal prices to drive higher demands were identified.

In a condition where the capacities of production, disposal and remanufacturing are limited Pan et al. [64] formulated a general model for capacitated dynamic lot sizing problems in closed-loop supply chain, and solved to optimality using dynamic programming algorithm under different scenario.

6.3 Production Planning

Shi et al. [65] studied the optimal production and pricing policy for a closed loop system, where manufacturer has two channels to satisfy the demand, which are new and remanufactured products. A model is developed to maximize the overall profit by simultaneously determining the selling price, the production quantities for new and remanufactured products, and the acquisition price of used products. The impacts of uncertainty in demand and returns were investigated and followed up by subsequent research. Shi et al. [66] then developed an optimal production planning for a multi-product closed loop system considering both demand and return uncertainty. A Lagrangian relaxation based approach is developed to solve the problem. In terms of uncertainty from machine failures, Kenne et al. [67] studied production planning and control of a single product involving combined manufacturing and remanufacturing operations within a closed-supply chain with uncertainty from machine random failures and repairs, and developed a model that minimizes the sum of the holding and backlog costs for manufacturing and remanufacturing products.

6.4 Capacity Planning

Due to the increasing number of product offering with shorter life-cycle, recovery processes in CLSC became more complex when capacity is limited. Georgiadis et al. [68] studied the impact of product lifecycle on capacity planning of CLSC with remanufacturing, and found that life-cycle characteristics influenced the type of collection and remanufacturing capacity planning policies to perform at their best. Vlachos et al. [69] proposed a system dynamic model for dynamic capacity planning of remanufacturing, taking into account not only economic but also environmental issues, while Georgiadis & Athanasiou [70] studied the impact of two-product joint lifecycles on capacity planning of remanufacturing networks, an extension from Georgiadis' work under single product.

7. Summary and Research Opportunities

In this paper, we have reviewed literatures on closed loop supply chain with remanufacturing and categorized them into several perspectives. Table 2 is the summary of the review, presented by research perspectives and the year of publication. The result showed that research on closed-loop supply chain has grown significantly over the last decade, especially during 2007 to 2011.

On the managerial aspect, CLSC strategy and policy were discussed intensively during 2007 to 2009, but in recent years, performance assessment and business perspective have taken the lead on studies on CLSC with remanufacturing. Leadership and organization is the least topic discussed despite their importance in the adoption of closed loop supply chain management.

From the technical aspect, we found that research on network design has received growing attention. Most of the works were aimed at finding the optimum network in terms of location allocation decisions. Uncertainty is inevitable in a closed loop supply chain due to the unknown quantity and quality of returns that can influence the overall network, forward as well as reverse channel. However, the efforts to tackle this problem were limited and recently have shifted to technology innovation and product design approach. The objective is to minimize the source of uncertainty of product returns, rather than capturing the uncertainty by means of stochastic models where the latter usually significantly increases the problem complexity. Identification tools such as RFID tags and SEPs were considered in some papers. Also, modular design for better disassembly process was introduced.

Table 2: Mapping of articles based on research perspective and years of publication

Research Perspective		2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Managerial Aspect	Leadership & Organization									19			
	Strategy & Policy			21			28, 33	3, 20, 22, 25, 31, 37	23, 24, 27, 29, 32, 36	18, 25, 34	26	38	30
	Performance & Assessment											39, 40, 41, 42	
	Business Perspective			13		43						44, 45	
Technical Aspect	Network Design	11				46, 47				48, 49, 51	50, 52, 55, 57	53, 54, 56, 58	
	Inventory Management			59			60		61	64	62	63	
	Production Planning										65	66, 67	
	Capacity Planning						68	69			70		

Finally, we present an outline of research opportunities that are synthesized from reviewed articles and from our perspective and understanding:

- Management commitment in terms of leadership, financial, and resources supports are vital to any initiatives where extra efforts, such as managing returns, are needed. Also, some findings indicated that decentralization is a better approach for more efficient and effective CLSC practices, therefore a strong leadership in each chain is important. A study on the CLSC system behavior under the effect of certain leadership style and organization is desirable for better understanding in the CLSC orientation.
- Performance & Assessment on CLSC with remanufacturing is noticeably growing even though is still in its infancy stage. There have been numerous studies claimed that CLSC enhances profitability and reduces environmental impacts, therefore it is necessary to build constructs, framework, models and tools for CLSC performance assessment or measurement. Key indicator of its performance could be related to economical or environmental benefits, or both. Profitability and efficiency should be among economic indicators, while eco-footprint and life-cycle assessment could be the measurement tools for environmental benefits. It is a widely open research opportunities to explore.
- Managing returns involves many levels of uncertainty, and recently, the use of sensor technology such as RFID and SEPs have been proposed to reduce uncertainties. Therefore, exploration is needed for identifying various sensor technology innovation, implementation strategies, tactical and operational issues in implementing them and the effects of the technology to CLSC performance, and may serve as an agenda for further research.
- CLSC with remanufacturing have become increasingly important in industries' practices because product life cycle is getting shorter [18], for example mobile phones and entertainment gadgets. Most of the research on CLSC do not consider time sensitive characteristic, which leave this area not well explored. Short life cycle products influence CLSC in many ways, from collection of returns, inspection and selection, remanufacturing, distribution and remarketing activities. Optimal network design for collection, inspection and sorting are important since the product is time sensitive. Inventory management of short life cycle product should be managed accordingly to reduce the loss of value due to longer holding time. Production planning decisions are also influenced by the time sensitive characteristic of the products. Strategies to capture highest value of time sensitive returns should also be considered, such as incentives to reduce resident time, modular design for faster disassembly, and organization structure that supports the CLSC. These issues should call for a research agenda exploring all aspects of CLSC for products with short life cycle. This literature review showed that very limited works has been done to accommodate the abovementioned problems. It is our intention to investigate and explore these issues. We propose research agenda as presented in Figure 2.

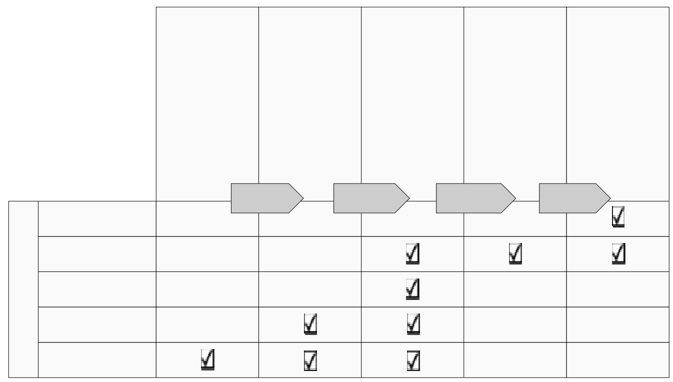

Fig. 2 Research Agenda on CLSC with remanufacturing for short life cycle products

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