A Content Analysis of the Closed-Loop Logistics: A Review

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Abstract

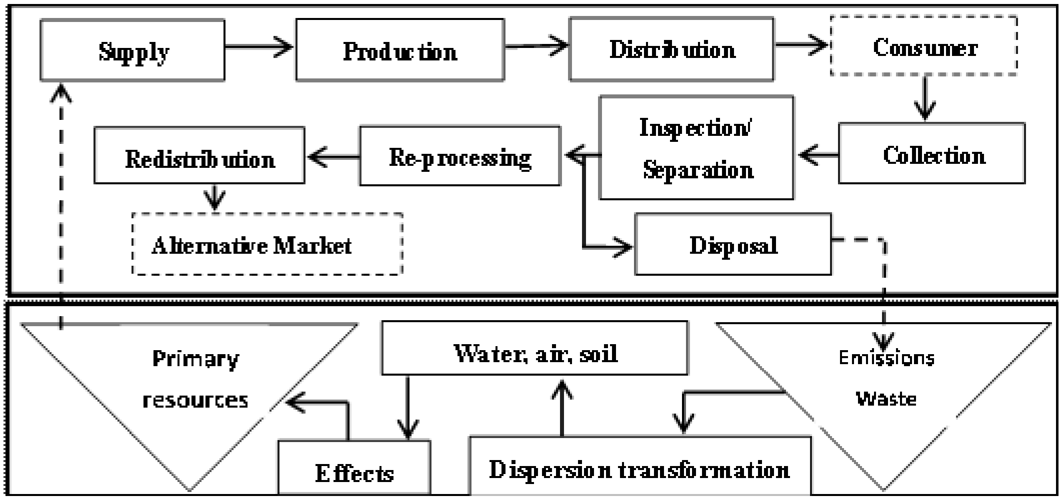
Recently, closed-loop logistics (forward and reverse logistics) has received more attention due to the customer expectations, increasing environmental concern, and economic aspects. Despite the growing body of literature on this topic, little effort has been devoted to synthesize the research on closed-loop logistics. A literature review is a valid approach and necessary step towards structuring a research field, and forms an integral part of any research conducted. It also helps to identify the conceptual content of the field and can contribute to theory development. The paper presents a literature review on closed-loop logistics by adopting the content analysis method that can capture formal aspects as well as content aspects by applying a systematic procedure. It includes four main steps: material collection, descriptive analysis, category selection, and material evaluation. To classify and evaluate the body of published literature, a taxonomy formed by three dimensions is defined: descriptive, modeling, and network structure dimensions. The review reveals that closed-loop logistics is new research area in supply chain field; there still remain opportunities for extending the literature base. It identifies some gaps in the literature and develops some propositions for future research directions such as integration of tactical and operational level decisions and fully development of product recovery network.

Keywords: Closed Loop Logistics, Literature review, Content analysis

1. Introduction

Implementation of legislation, social responsibility, corporate imaging, environmental concern, economic benefits and customer awareness are forcing original equipment manufacturers (OEMs) not only to provide more environmental friendly products but also to take back used products at their end of life (Mutha and Pokharel, 2009). This induces the concept of the green supply chain management and the closed-loop supply chain management. Different from a conventional supply chain, planning a green supply chain requires an additional function of recycling and thus, a closed-loop chain is a necessary infrastructure for material flow (Wang and Hsu, 2010). The closed-loop logistics (CLL) includes forward logistics and reverse logistics. The forward logistics encompasses material supply, production, distribution and consumption (Krikke et al., 2003). For the reverse logistics, the flow of used products includes collection, inspection/separation, re-processing, disposal, and redistribution (Fleischmann et al., 2000). Figure 1, describes forward and reverse processes in the supply chain and it also shows CLL environmental effects that eventually have (negative) impact on natural resources.

Figure 1 Closed-Loop Supply Chain and Environmental Chain Linked (Krikke Et Al., 2003)



Despite the growing body of literature on CLL, little effort at directed small scale has been devoted to synthesizing the researches on CLL. Also all comprehensive review papers focused on reverse logistics (Pokharel and Akshay, 2009, Chanintrakul et al., 2009, Fleischmann et al., 1997) , supply chain management(Sachan and Dattas, 2005, Carter and Easton, 2011), facility location (Melo et al., 2009, Owen and Daskin, 1998) or some specific dimensions of facility location (such as uncertainty) (Peidro et al., 2009, Snyder, 2006), and third-party logistics (Marasco, 2007, Selviaridis and Spring, 2007).

On the other hand, " a literature review is a valid approach and necessary step towards structuring a research field, and forms an integral part of any research conducted and also helps to identify the conceptual content of the field and can contribute to theory development"(Seuring et al., 2005). This paper investigates the field of research and practice in this topic through content analysis of the published literature. We have used various web based search engines, books and conference proceedings to locate and review the literature. The remainder of the paper is organized as follows: in section 2, CLL literature is reviewed by content analysis method that includes four main steps: material collection, descriptive analysis, category selection, and material evaluation. This section, also includes a summary review of the major papers. Finally, in section 3, conclusion and possible directions for future research is presented.

2. Review Methodology

In the paper, the content analysis method is used to review CLL literature. A content analysis can capture formal aspects as well as content aspects by applying a systematic procedure (Kolbe and Burnett, 1991). Figure 2, shows the process model of content analysis.

Figure 2 The process model of content analysis (Seuring et al., 2005)

Material Collection

In the first step, the papers to be collected are defined and delimitated. This might include taking a look at how the material emerged (Seuring et al., 2005). The review of published literature is limited to English electronic publications after 1990, e.g. Journal of Computers & Operations Research, Transportation Research, Operational Research Society, Production & Operations Managements, International Journal of Physical Distribution & Logistics Management, Applied Mathematical Modeling, European Journal of Operational Research, International Journal of Logistics Management, and finally Conference proceedings. Five famous search engines, that include all major international journals on logistics, supply chain management, and operations research, were used to explore most of the existing related literature: ScienceDirect, Web of Science, Springerlink, IEEEXplore, and Google Scholar databases for literature. Based on our experience team, researchers use different words to mention CLL. Therefore, we used keywords that are mostly frequently used in other papers in this field, such as 'integrated logistics', 'supply and return', 'closed-loop logistics', 'closed-loop supply', 'return distribution', 'supply loops', sustainable logistics, 'product returns', 'product recovery network', 'reverse logistics network', 'end of life cycle'. Thereby, related edited volumes and single papers in other journals could also be found. Then, cited references in the collected papers were used as a secondary source. Overall, 294 papers were identified using this method. In the second step of paper collection, three notes were made:

- Papers concentrated on CLL (supply chain) are included not only reverse logistics.
- Papers without considering a mathematical model in CLL are excluded.
- Only papers that at least include the location as an output in the field of CLL are cited.

At the end, 45 papers included all three above notes.

Descriptive Analysis

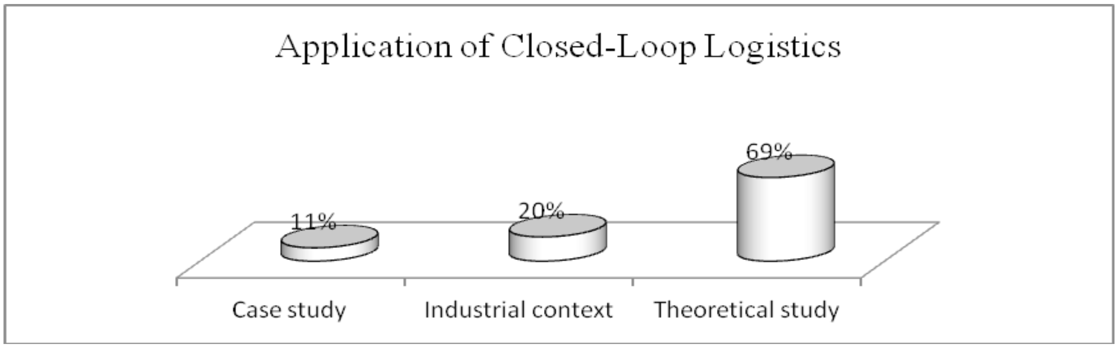
In the descriptive analysis, formal aspects of the materials are assessed. The distribution of the papers in the researched period (1990 – 2010) is displayed in Table 1. The numbers in the table indicate that research on CLL did not begin to appear significantly in scholarly journals until the late 1990s. Before 2001, only 2 papers have been published (1998 and 1999, respectively) and 5 papers between 2001 and 2005, while contributions published in the last period (after 2006) amount to 38, representing about 85% of the total number of collected papers. This shows CLL is a rather new research area in supply chain field. Table 1 presents that journals and conferences have collectively published about 73% and 27% of the total papers respectively. Based on the region, 62%, 16%, and 20% of papers are from Asia, USA, and Europe respectively. Without considering the conferences this ratio will be 49%, 21%, and 27% respectively.

Finally, the papers were classified according to the computational experiments to three criteria: case study, industrial context, and theoretical study. The category case study refers to the papers that use a real-life scenario for computational experiments, even if it was not implemented in practice, while the category industrial context stands for a study using randomly generated data for a specific industry (Melo et al., 2009). The category theoretical refers to a platform of random data instances and conducted a computational study. As can be seen from Figure 3, most of the papers are theoretical, and few are case studies or even industrial context.

Table 1 Distribution of Papers based on the Region and year Published

Journal/Conference	*Year published*			**Percentage**	*Asia*		*USA*	*Europe*	*Others*
	1990-2000	*2001-2005*	*2006-2010*		*China*	*others*			
Journals	2	3	28	73	2	14	7	9	1
Conferences	0	2	10	27	10	2	0	0	0
Total	2	5	38		12	16	7	9	1
Percentage	4	11	85	100	27	35	16	20	2

Figure 3 Papers Classification according to the Computational Experiments



Category Selection

In this step, "structural dimensions and related analytic categories are selected, which are to be applied in the literature review to structure the field" (Seuring et al., 2005). For a structuring content analysis of literature, we chose the following dimensions based on other review papers in the area of reverse logistics (Pokharel and Akshay, 2009, Chanintrakul et al., 2009, Fleischmann et al., 1997) , facility location and supply chain management (Melo et al., 2009, Owen and Daskin, 1998, Peidro et al., 2009, SNYDER, 2006), and third-party logistics (Marasco, 2007) also our team experience during study in this field.

- In the modeling dimensions, papers were categorized according to the type of problems, source of uncertainty, modeling approaches, objective functions, solution approaches, and outputs.
- The network structure dimensions includes the number of product and period, flow and facility capacity, number of layer in forward and reverse logistics, number of layer in location decisions, responsibility of network, type of cost, logistics network stages, product recovery options.

Literature Evaluation

Modeling Dimensions Evaluation

The modeling dimensions in the literature are analyzed based on the 6 basic factors that are shown from Table 2 to 5 and Figure 4. Throughout the course of this study, it has been observed that:

Type of problems

Deterministic formulations assume that input parameters are known values or that they vary deterministically over time. However, Dekker et al. (Dekker et al., 2004) remark that customer behavior provides several uncertainties in time, demand, channel, and quality of return especially in reverse logistics that, the customer has become an integral part of the logistics network. Research on stochastic location problems can be divided into two primary approaches as the probabilistic approach and the scenario planning approach. In both cases, any number of system parameters might be taken as uncertain, including time, construction costs, demand locations, and demand quantities. Probabilistic models explicitly consider the probability distributions of the modeled random variables, while scenario planning models consider a generated set of possible future variable values. Scenario planning is a method in which decision makers capture uncertainty by specifying a number of possible future states (Owen and Daskin, 1998). As seen, in Table 2, 40% of the surveyed papers deal with stochastic parameters and approximately 33% of these papers consider the scenario planning problem.

Table 2 Papers Classification According to the type of problem and Source of Uncertainty

Source of uncertainty	Stochastic model		Deterministic model
	Probabilistic	Scenario planning	
Demand of product	(Zhou et al., 2005, Yong et al., 2006, Mao et al., 2007, Gong et al., 2009, Lee and Dong, 2009, Wang and Zhao, 2009, Yang et al., 2009, Wang and Hsu, 2010, Pishvaee and Torabi, 2010)	(Lee et al., 2007, Listes, 2007, Salema et al., 2007, El-Sayed et al., 2010, Lee et al., 2010, Pishvaee et al., 2009)	The rest of Papers are deterministic
Quantity of used product	(Sim et al., 2004, Zhou et al., 2005, Yong et al., 2006, Mao et al., 2007, Gong et al., 2009, Lee and Dong, 2009, Wang and Zhao, 2009, Yang et al., 2009, Pishvaee and Torabi, 2010, Pishvaee et al., 2011)	(Lee et al., 2007, Listes, 2007, Salema et al., 2007, El-Sayed et al., 2010, Lee et al., 2010, Pishvaee et al., 2009)	
Cost	(Pishvaee and Torabi, 2010, Pishvaee et al., 2011, Yong et al., 2006)	(Pishvaee et al., 2009)	
Disposal rate	(Wang and Hsu, 2010, Pishvaee and Torabi, 2010)	(Pishvaee et al., 2009)	
Reusable rate of used product	(Wang and Hsu, 2010)	(Lee et al., 2007)	
Demand of remanufacture	(Pishvaee et al., 2011)		
Capacity	(Pishvaee and Torabi, 2010)		
Time	(Pishvaee & Torabi, 2010)		

Source of uncertainty

During the time, any of the parameters of the CLL problem (rate of used product, capacity, and demands) may fluctuate. Parameter estimates may also be inaccurate due to poor measurements or to tasks inherent in the modeling process. As seen, in Table 2, the most contemplated source of uncertainty is demand uncertainty and quantity of used products. The remaining sources of uncertainty are similarly important as far as their consideration within the models is concerned. Pishvaee et al. (Pishvaee and Torabi, 2010, Pishvaee et al., 2011) are the only researchers that considered uncertainty in time, demand of remanufactured products, and capacity in addition to the unknown demand, quantity of used products, disposal rate, and cost.

Modeling approaches

Most of the deterministic problems are solved with mixed integer linear programming (MILP) (25/29 surveyed papers, Table 3). However, with increasing reality in a MILP model, the required data and computational process expand tremendously especially in a large scale problem that the model accuracy and data reliability also decrease (Pishvaee et al., 2010). In the field of stochastic modeling, most of researchers used stochastic mixed integer programming as a modeling approach technique that is capable of dealing with the stochastic parameters present in data (10 surveyed papers over 17). Ben-Tal et al. (Ben-Tal et al., 2009) mention that, in stochastic optimization, the uncertain numerical data are assumed to be random. In the simplest case, these random data obey a known in advance probability distribution, while in more advanced setting, this distribution is only partially known. Pishvaee et al. (Pishvaee et al., 2011) mention two major drawbacks of stochastic optimization: (i) in stochastic optimization, the solution is immunized in some probabilistic sense to stochastic uncertainty and thus the solution could be infeasible for some realizations. Although this happens with very small probability, it could still bring high costs; (ii) in the case of scenario-based stochastic programming, the large number of scenarios used in representing the uncertainty can lead to large-sized, computationally challenging problems. Pishvaee et al. (Pishvaee and Torabi, 2010, Pishvaee et al., 2011) use the robust optimization approach (RMIP) and probabilistic programming (PMIP) for dealing with problems. Inuiguchi & Ramik (Inuiguchi and Ramik, 2000) state two differences between fuzzy and stochastic programming: (i) for a general distribution (except normal distribution), a stochastic programming problem cannot usually be solved easily, in contrast, a fuzzy mathematical programming problem can be solved easily; (ii) if the uncertain variables are independent then , only a small number of decision variables take non-zero values in the optimal solution of the fuzzy mathematical programming problem. On the other hand, a large number of decision variables take non-zero values in the optimal solution of the stochastic programming problem. Hsu & Wang (Wang and Hsu, 2010) express the uncertainty by fuzzy and interval numbers, also Yong et al.(Yong et al., 2006) and Gong et al. (Gong et al., 2009) model the problem using fuzzy mixed integer programming (FMIP).

Table 3 Papers Classification According to the type of Problem and Modeling Approach

Modeling approach	*Stochastic model*	*Deterministic model*
ILP	(Yang et al., 2009)	----
MILP	(Sim et al., 2004, Lee et al., 2007, Listes, 2007, Mao et al., 2007, Salema et al., 2007, Lee and Dong, 2009, Pishvaee et al., 2009, El-Sayed et al., 2010, Lee et al., 2010, Wang and Zhao, 2009)	The rest of papers
MINLP	(Zhou et al., 2005)	(Liu and Ni, 2007, Du et al., 2009, Ko and Evans, 2007)
Robust MILP	(Pishvaee et al., 2011)	----
Fuzzy MILP	(Yong et al., 2006, Gong et al., 2009, Wang and Hsu, 2010)	----
Possibilistic MILP	(Pishvaee and Torabi, 2010)	----

Objective functions

The type of objective function that measures CLL network performance is displayed by Table 4. The minimization of total costs is the most common objectives that is used in most of papers as a single objective through the sum of different type of cost that depend on the set of decisions modeled (39 papers). In contrast, profit maximization has received much less attention from researchers (3 papers). Real world network design problems are often characterized by multiple and conflicting objectives. In this case, in addition to economic factors, resource utilization and network responsiveness are considered. Network responsiveness is an important issue in reverse logistics. It is undesirable for customers/retailers to keep used products for a long time because of the related holding costs. Since customers have a tendency to discard used products as soon as possible, companies aiming to collect more used products from customers should also consider network responsiveness when minimizing costs (Pishvaee et al., 2010). Lee et al. (Lee et al., 2007a) consider a bi-objective function that includes reverse responsiveness maximization along with cost minimization. Pishvaee et al. (Pishvaee et al., 2010) propose a multi-objective model that in addition to reverse responsiveness maximization and cost minimization also includes forward responsiveness. Pishvaee & Torabi (Pishvaee and Torabi, 2010) model a bi-objective that comprises time delivery minimization and cost minimization.

Table 4 Papers Classification According to the type of Problem and type of objective Function

Type of objective	*Stochastic model*	*Deterministic model*
Minimum cost	(Sim et al., 2004, Zhou et al., 2005, Yong et al., 2006, Lee et al., 2007, Mao et al., 2007, Salema et al., 2007, Gong et al., 2009, Lee and Dong, 2009, Pishvaee et al., 2009, Wang and Zhao, 2009, Yang et al., 2009, Lee et al., 2010, Wang and Hsu, 2010, Pishvaee et al., 2011)	The rest of papers
Maximum profit	(Listes, 2007, El-Sayed et al., 2010)	(Salema et al., 2009)
Multi Objective	(Pishvaee and Torabi, 2010)	(Lee et al., 2007a, Pishvaee et al., 2010)

Solution approaches

A suitable technique solution is chosen based on the model type, number of constraints and decision variables. Melo et al. (Melo et al., 2009) classify the type of solution approach into two main parts, general- purpose software and specific algorithm. The category General Solver refers to the use of mathematical programming software to solve a problem either to optimality or until a solution is obtained within a prespecified gap reflecting the "worst" quality accepted by the decision-maker such as CPLEX, XPRESS, and LINGO. The specific algorithm is divided into two further types of solution. The category of specific algorithm-exact solution includes special-purpose techniques such as branch-and-bound, branch-and-cut, column generation, and decomposition methods that branch-and-bound algorithms sometimes also combined with Lagrangian relaxation or heuristic procedures to obtain bounds. The category of specific algorithm-heuristic solution contains heuristics and meta-heuristics like greedy algorithm, tabu search, simulated annealing, and ant colony. According to the literature, among the latter category, the genetic algorithm is a popular solution scheme that sometimes combined with other heuristics and meta-heuristics algorithm to obtain a hybrid-heuristics algorithm (Table 5).

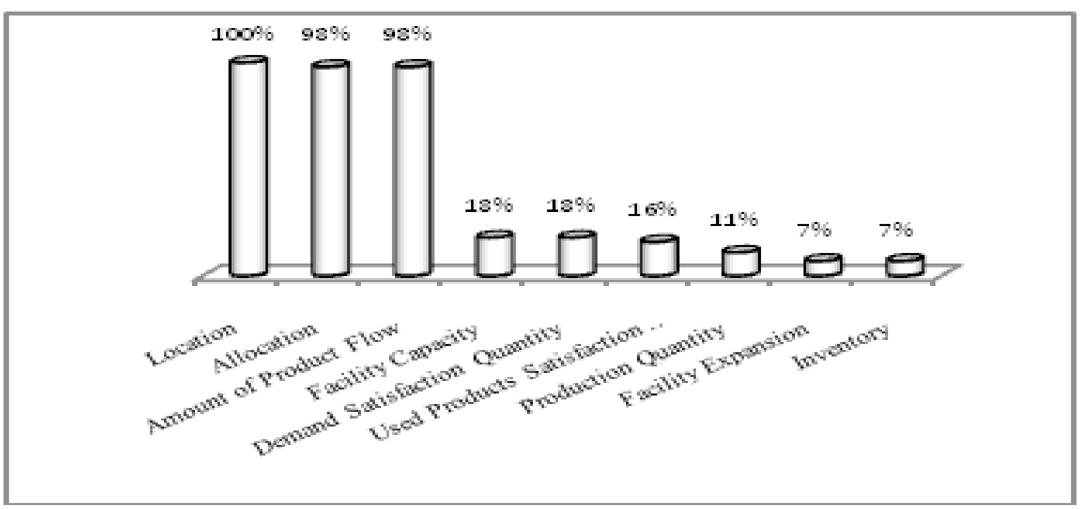
Outputs

There are several planning decisions (outputs) in CLL problem that number of them has a direct impact on the complexity level of problem. Figure 4 classifies the literature according to typical supply chain outputs. It clearly shows that tactical and operational decisions like inventory, production quantity have received less attention and even has not be mentioned to some of them such as routing and transportation modes besides of facility location, allocation, and flow of product.

Table 5 Papers Classification according to the type of Problem and solution approach

Solution approach	*Stochastic model*	*Deterministic model*
Specific algorithm- exact solution	(Listes, 2007)	(Marin and Pelegrin, 1998, Lu and Bostel, 2007, Uster et al., 2007, Easwaran and Uster, 2010)
Specific algorithm- heuristic solution	(Sim et al., 2004, Zhou et al., 2005, Yong et al., 2006, Lee et al., 2007, Mao et al., 2007, Gong et al., 2009, Lee and Dong, 2009, Wang and Zhao, 2009, Yang et al., 2009, Lee et al., 2010, Wang and Hsu, 2010, Pishvaee and Torabi, 2010)	(Guo and Tang, 2007, Ko and Evans, 2007, Liu and Ni, 2007, Lee et al., 2007a, Lee et al., 2007b, Lee and Dong, 2008, Min and Ko, 2008, Du et al., 2009, Easwaran and Uster, 2009, Wang and Hsu, 2010, Zarei et al., 2010, Pishvaee et al., 2010)
General solver	(Salema et al., 2007, Pishvaee et al., 2009, El-Sayed et al., 2010, Pishvaee et al., 2011)	The rest of papers

Figure 4 Papers Classification according to the Outputs



Network Structure Dimensions Evaluation

In this section, some features are identified that have an important role in a structure of facility location network: number of period, number of layer in forward and reverse logistics (centralization) and also location decisions, and finally logistics network stages.

Period

Use of multi- periods in CLL problems helps to determine the best schedule for opening, closing or even extension of existing facilities as an optimal location and relocation strategy for the planning period (Owen and Daskin, 1998) but most of the literature deal with single-period problems (approximately 73% of the surveyed papers) rather than dynamic programming.

Centralization

One of the main differences between closed-loop networks is the degree of centralization. Fleischmann et al. (Fleischmann et al., 2000) refer centralization to "the number of locations at which similar activities are carried out. In a centralized network each activity is installed at a few locations only, whereas in a decentralized network the same operation is carried out at several different locations in parallel. Centralization may thus be seen as a measure for the horizontal integration or `width' of a network. Analogously, the number of layers, referring to the number of facilities a goods flow visits sequentially, indicates the `depth or vertical integration of a network. In a single-level network all activities are integrated in one type of facility while in a multi-layers network different activities are carried out at different locations. The fact that multi-layers networks are considered does not mean that location decisions are allowed in all of them (Melo et al., 2009) and also the flow of goods in forward and reverse logistics usually passes from different facilities in forward and reverse logistics. Around 45% of papers have used a hybrid center that usually includes Distribution/ redistribution and collection centers and most of the authors consider manufacturing and recovery centers at the same place.

Network stages

Thierry et al. (Thierry et al., 1995) define the management of all used and discarded products, components, and materials as a product recovery management that fall under the responsibility of a manufacturing company. Product recovery management comprises five product recovery options: repair, refurbishing, remanufacturing, cannibalization, and recycling that have been explained in Figure 5. Product recovery options play an important role in reverse logistics, however, most of the papers do not mention clearly and fully to this aspect of CLL network.

3. Conclusion And Future Research Directions

The literature on CLL has been growing sharply during last few years. Roughly more than 80 percent of the literature cited in this review paper was published in the past 5 years and only around 5 percent were published before 2000. The growing interest in this context is due to the customer expectations, increasing environmental concern, and economic aspects. In this review, we have attempted to present an overview of CLL by adopting the content analysis method. To classify this literature review, a taxonomy formed by three dimensions was defined: descriptive, modeling, and network structure dimensions. With this paper, we hope to contribute to a better understanding of the situation of existed papers in CLL and to specify further possible research directions in this field.

- Development of new modeling approaches for uncertainty. According to the drawbacks of stochastic approach and its disadvantages, applying robust approach and possibilistic approach are more suitable in this direction.
- Applying modeling approaches for real world cases rather than theoretical or even industrial context due to the existing considerable gap between theoretical work and empirical studies.
- A comparative study among the different heuristic, meta-heuristic, and hybrid heuristic algorithms that can help to identify the advantages and disadvantages of each method in the context of CLL.
- Integration of tactical and operational level decisions such as inventory, production, routing, and transportation modes with strategic level decisions in CLL.
- Development of multi-objective with considering customer satisfaction along with cost minimization or profit maximization in stochastic problems. Also propose a new solution approach in the case of

multi-objective function with the presence of multiple conflicting objectives.

- The review also shows that a significant portion of research in the field of CLL considers a single objective, although most real-world problems involve more than one objective.
- Fully development of product recovery network by new modeling approaches that capture uncertainty and additional structural considerations for more complete analysis and better decision making. Returned products are a far less homogeneous and standardized input resource than traditional raw materials and new parts. To handle this uncertainty adequately is one of the main responsibilities in the product recovery network.

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