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An Insight into Reverse Logistics with a Focus on Collection Systems

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Abstract: Sustainable development is now the focus of researchers and organizations worldwide. Several concepts, such as reverse logistics (RLs) and closed-loop supply chains, have been introduced to encourage sustainability in supply chains. RLs refers to the set of activities needed by consumers to collect the product used for reuse, repair, remanufacturing, recycling, or disposal of the used product. There are various processes involved in RL, and one of them is collection systems. Collection refers to a company obtaining custody of specific items. We review the literature on RLs collection systems. A bibliometric analysis was conducted to provide better insight into the field and establish any trends. Firstly, we present the classification methods used in the field, based on available review papers. Secondly, we evaluate literature from several fields that are related to either the problem setting or the technical features. Different perspectives are presented and classified. This method facilitates the identification of manuscripts related to the reader's specific interests. Throughout the literature review, trends in measuring the performance of collection systems are identified, and directions for future research are identified and presented.

Keywords: reverse logistics; collection system; sustainability; remanufacturing

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1. Introduction

Many consumers of electronic products stop using them before the end of their lifetime. These customers often treat the used product as garbage, as they do not know how to deal with it. This situation creates economic, social, and environmental problems for the region, which are concerning for the government, society, and product manufacturer. Recently, manufacturers have volunteered or been forced to reverse their supply chain to create sustainable supply chain management.

Interest in researching reverse supply chains (RSCs) and reverse logistic (RLs) is growing, as indicated by large quantities of publications in the field. The literature especially review papers have split the field into two themes: specific aspects of RLs, such as modeling [1], RL planning [2], drivers [3], performance measures [4], and structure [5], and a general overview of RL [6,7]. Figure 1 shows the basic concept of RL.

Moreover, there are many review papers that summarize the technical articles and identify and classify the research according to different criteria (Table 1).

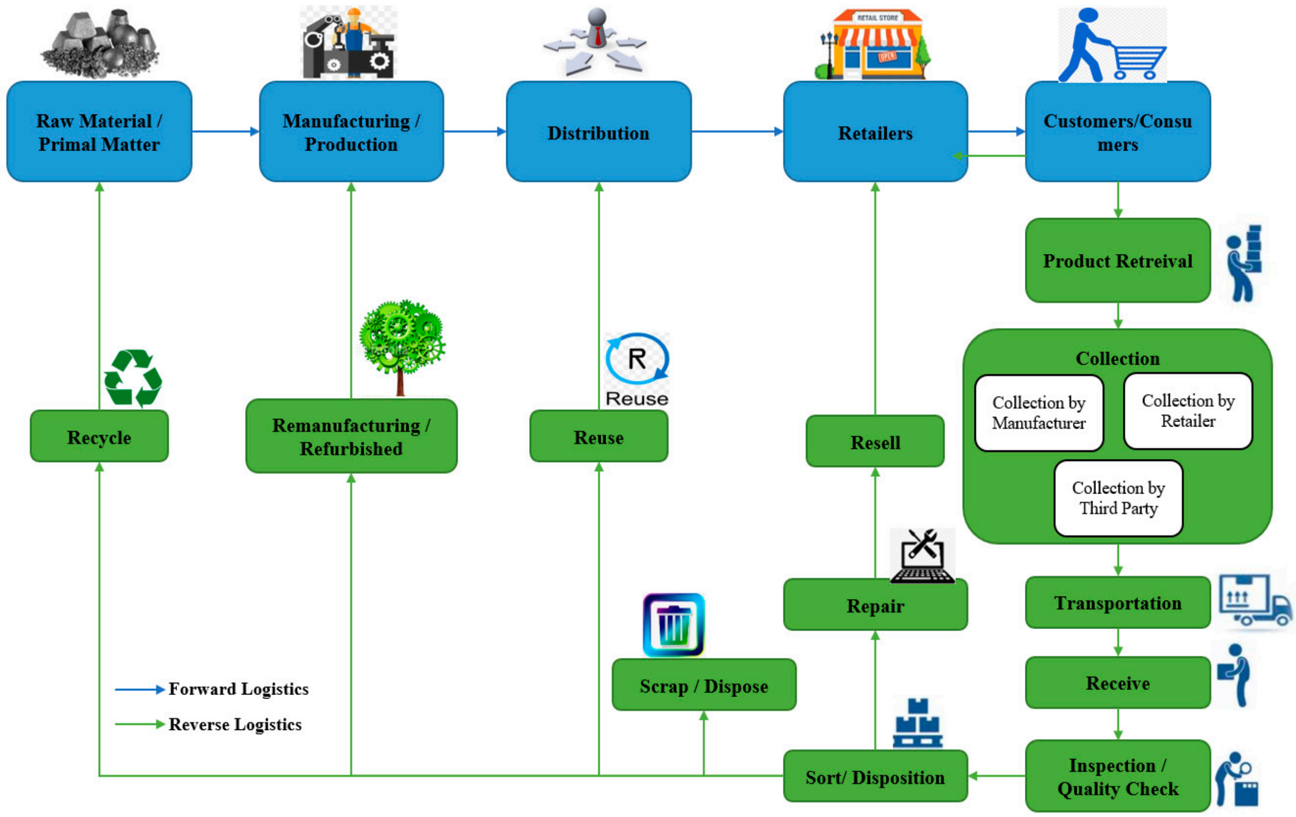

Figure 1. Basic concept of reverse logistics.

Table 1. Literature reviews during the last decade on reverse logistics.

Reference	Year of Publication	Scope	Finding	Year Under Consideration	No. of Articles Reviewed
E. Shekarian [8]	2020	CLSC/RL	CLSC categories based on game theory articles	2004–2018	215
K. Mathiyazhagan et al. [9]	2020	CLSC/RL	Classification in forward and backward supply chain	2002–2017	204
F. Jaehn and R. Juopperi [2]	2019	RL	Identifying RL planning in paper industry	2009	
L. L. Tombido et al. [4]	2018	CLSC/RL	Performance measures and technological use	2000–2018	134
M. T. Islam and N. Huda [10]	2018	CLSC/RL	Classification of four research types in E-waste product (designing and planning of reverse distribution, decision making and performance evaluation, conceptual framework, and qualitative studies)	1999–2017	157
S. C. Thaba [3]	2017	RL	Identifying drivers		
M. G. Moniveena et al. [11]	2017	RL	Identify the regulation of reverse logistic for pharmaceutical industry		
S. Guo et al. [5]	2017	RL	Classification of supply chain structure (contract, link, and leadership)	2006–2016	62
K. Govindan and H. Soleimani [12]	2017	CLSC/RL	Trend in CLSC/RL in Journal of Cleaner Production	~2014	83
E. A. R. de Campos et al. [13]	2017	RL	Classification of four research types in pharmaceutical industry (environmental risk, evolution and regulatory, and stakeholder's educational perspective)	1996–2015	39
E. Bazan et al. [1]	2016	RL	Identifying mathematical modeling of RL inventory systems	1967–2014	183
A. H. Vahabzadeh and R. B. M. Yusuff [14]	2015	RL	Identifying RL characteristic, modeling, and stakeholder RL	1998–2012	
A. Taghipour et al. [15]	2015	RL, RM	Identifying the aspect of design for remanufacture		
J. Rezaei [16]	2015	RL	Categorizing the multicriteria decision making in RL		
K. Govindan et al. [7]	2015	CLSC/RL	The whole area in RL and CLSC	2007–2013	382
S. Bhakthavatchalam et al. [17]	2015	CLSC	Categorizing the problem (quality, reliability, maintenance and warranty), and mathematical tools and techniques		
S. Agrawal et al. [18]	2015	RL	Classification of the references (forecasting, outsourcing, networks design from secondary market perspective, and disposition decisions)	1986–2015	242
J. W. Gan and Z. G. He [19]	2014	RL	Classification of four research types in vehicle industry (trend, performance measure of recycling, recycling mode, RL system and network)		
R. P. Andrade et al. [20]	2014	RL	Identifying the influence of RL on the enterprise competitiveness		
D. W. Steeneck and S. C. Sarin [21]	2013	RL	Identifying the correlation of the pricing of remanufactured products to the production cost		
G. C. Souza [22]	2013	CLSC	Framework design tutorial		
H. K. Chan et al. [23]	2010	RL	Identifying the correlation of Just In Time and RL	~2009	125
S. Pokharel and A. Mutha [6]	2009	CLSC/RL	Classification of RL processes (logistics, business, production, and operations management)	1971–2008	164
P. Chanintrakul et al. [24]	2008	RL	RL Network design	2000–2008	

RL: Reverse logistic; CLSC: Close Loop Supply Chain; RM: Remanufacturing.

An interesting component of RLs that has been reviewed is the collection system. However, to the best of our knowledge, there is no information published about the collection system considering only manufacturing as the product recovery option. The RSCs consists of collection activity and a recovery option [6]. The collection activity includes product acquisition from the customers, inspection, and transportation of the product back to the recovery systems, such as remanufacturing, recycling, repairing, or reuse (Figure 1). Additionally, some economic and legislation policies have been implemented to support the collection system. However, these policies are ineffective and fail to improve the product return rate [25]. Therefore, both the government and the remanufacturer need to collaborate to develop a competent collection strategy [26]. The collection strategy is an essential factor in the RSCs. However, consumer awareness about the collection channel and their limited knowledge about the benefit of returning the product are an obstacle to the strategy. Therefore, consumers should be encouraged to return their used goods and need to be well-informed about the collection centers to make the collection process more viable and lucrative [26]. Figure 2 depicts the RSC collection system.

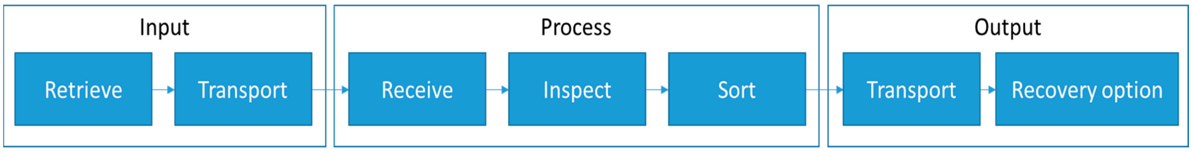

Figure 2. Reverse supply chain collection system.

The main aim of this paper is to provide an in-depth insight into the RL, present its various aspects, as well as classify the research based on RL's performance measures. The motivation of this review paper is to neatly review recent progress in RL, so the readers will acquire a good knowledge about this well-established area. Through the presented literature, the gaps in the literature are identified and reported as future research directions. The authors make an effort to answer the following research questions: (1) What are various aspects in RL research? (2) In which directions RL research is heading towards?, and (3) What are different performance measures, solution methods, and constraints in RL? The later sections of this paper are structured as follows. Section 2 provides the methodology adopted for this research work. Section 3 presents the RLs characteristics and decision delineation. It consists of information on RLs criteria and indicating what type of decision has to be made. Section 4 explains the measurement and constraints that occur in addressing the problem and the objectives or measurement to be considered. The method used for the solution and incorporation of uncertainty, which indicate the type of solution or evaluation technique that is used and distinguishes between deterministic and stochastic manuscripts is explained in Section 5. The application area and applicability of research, indicating to which area the problem is situated and information on the testing (data) and its implementation in practice is presented in Section 6. Lastly, Section 7 presents the discussion, conclusions, and future research work.

2. Methodology

A brief bibliometric analysis was conducted to understand more about RLs and the other factors, such as journals that are more popular in this field, influential authors, and institutes working in this area, etc. Later, various factors, characteristics, performance measures, constraints, and aspects of RL that are discussed in the literature are presented in detail to answer the research questions mentioned in the Introduction section.

Bibliometric Analysis

Bibliometric analysis is the analysis of published articles, citations, and sources of information. This type of research enables researchers and specialists to analyze a specific research field by considering research articles, journals, authors, institutions, and countries, enabling researchers to obtain a general picture of the research field. In the literature, many researchers have published bibliometric research in a diversity of fields [27–42]. However, in the research area of RLs, there are no existing bibliometric studies. This paper aims to provide an overall picture of research from the starting phase of this field, nearly 23 years ago. An overview of the most productive and influential research in the field of RLs is presented here based on the information gathered from the Web of Science (WOS) database.

The two keywords "reverse logistics" and "reverse supply chain" were used as keywords in the "Topic" section of the literature search. This search collated all the articles belonging to this field. The data collection process was completed in November 2020, and 3414 documents were found for this topic, including journal articles, proceedings papers, books, notes, comments, reviews, and editorial material. In this article, we focused on journal articles and reviews. The results were filtered accordingly, reducing the total number of publications to 2307 papers. It was revealed that the majority of these articles were published during the last decade.

Research related to RL and RSC has recently attracted more interest from researchers, which is demonstrated by annual increases in the number of publications in this field, as shown in Figure 3. There is definitely an increase in the number of researchers in this area, and the WOS database has included more journals recently. According to WOS records, more than 200 papers have been published annually in the field of RSC since 2016, and 341 articles were published in 2019.

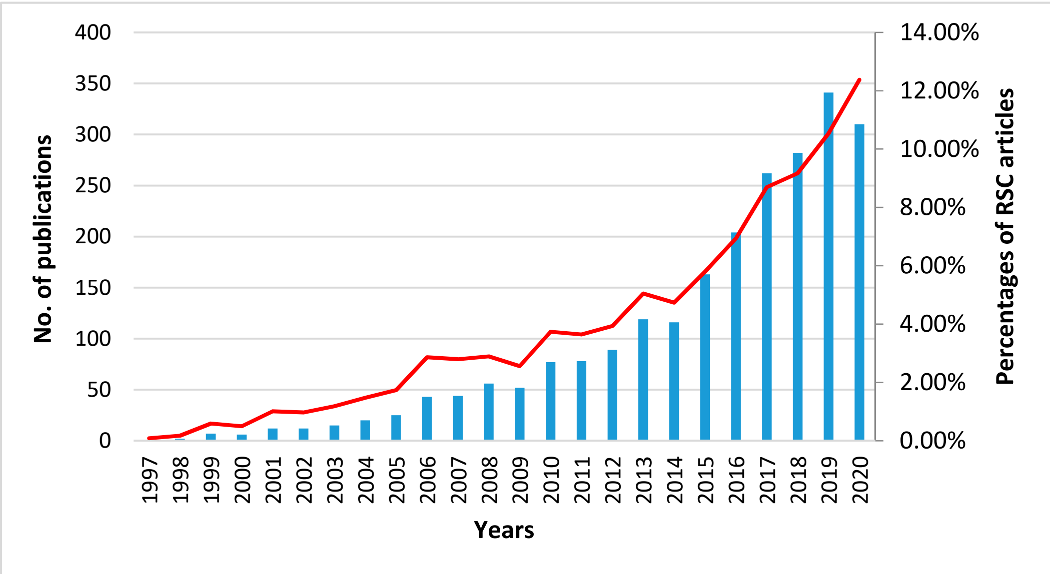

Figure 3. Number of annual publications in reverse supply chain (RSC) research. The blue bar indicates the total number of yearly RSC papers, and the red line indicates the ratio of yearly RSC publications to the total publications in all fields × 10,000.

As the interest of researchers is increasing in the field of RLs, an increase in citations and a higher citation rate is expected. We found that 138 papers had more than 100 citations and 12.6% of the total publications on RSC were cited more than 50 times (Table 2). A further interesting activity is to analyze the global H-index [43] for RSC research. The H-index [44] is a measure that aims to represent the importance of a set of papers. The H-index for the papers collected in this research study was 126.

Table 2. Citation structure of papers in the field of reverse supply chain research.

Number of Citations	Number of Papers	% Papers
≥100 citations	138	6.0%
≥50 citations	291	12.6%
≥20 citations	476	20.6%
<20 citations	1402	60.8%
Total	2307	100.0%

RSCs research is currently published in various journals, with more than 400 journals in the WOS. Table 3 shows the 10 most influential journals sorted by the number of publications in the field. The Journal of Cleaner Production and International Journal of Production Economics are the most influential journals in terms of the number of publications, whereas the European Journal of Operational Research has the most citations per item.

Table 3. Most influential journals that reverse supply chain research was published in.

Rank	Journal	No. of Publications	Times Cited	Citations/Article
1	JCP	259	7584	29.28
2	IJPE	153	8628	56.39
3	IJPR	131	3942	30.09
4	Sustainability	83	544	6.55
5	CIE	79	2865	36.27
6	RCR	79	3636	46.03
7	EJOR	65	7689	118.29
8	IJAMT	42	1312	31.24
9	OMEGA	36	3053	84.81
10	IJLM	34	543	15.97

JCP—Journal of Cleaner Production; IJPE—International Journal of Production Economics; IJPR—International Journal of Production Research; CIE—Computers and Industrial Engineering; RCR—Resources, Conservation & Recycling; EJOR—European Journal of Operational Research; IJAMT—International Journal of Advanced Manufacturing Technology; IJLM—International Journal of Logistics Management.

Trend analysis was conducted on the most influential journals to generate more useful information. The entire study period was divided into several intervals, and the most influential journals within each interval were analyzed to assess the trends, as shown in Figure 4. The results show that the Journal of Cleaner Production and the Sustainability journal have published the most RSC research in recent years.

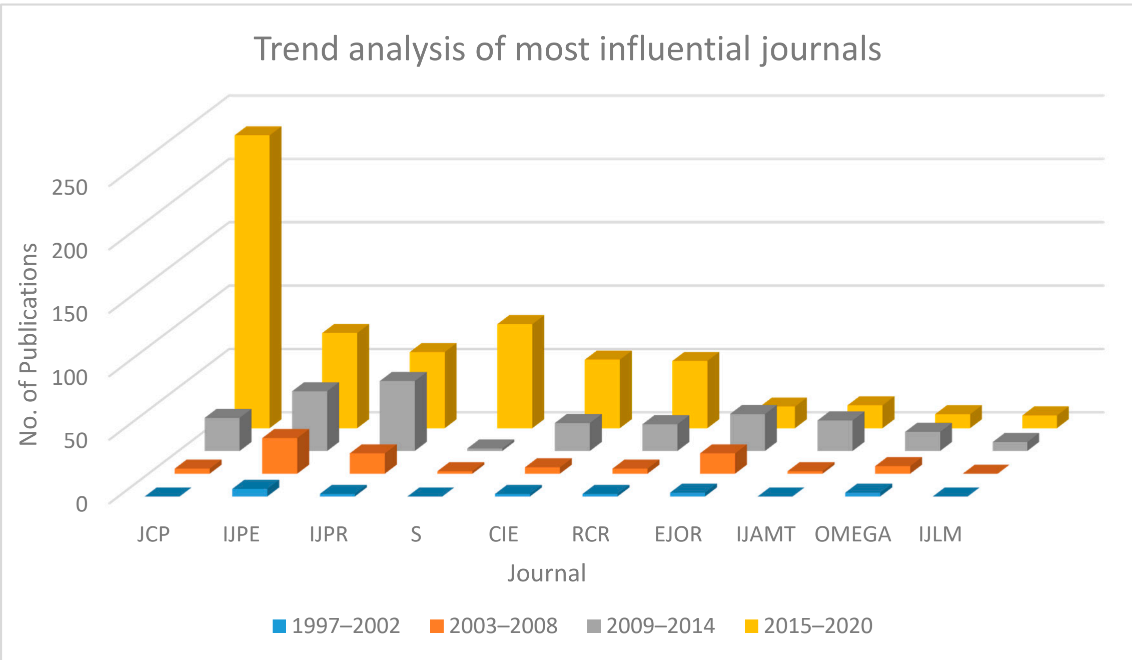

Figure 4. Trend analysis of the most influential journals in reverse supply chain research.

To determine the most important papers in the RSC field, the search results were sorted according to the most cited papers. Therefore, it is possible to collect articles that have received more citations in the field of RSC. The higher the number of citations received by an article, the more important and popular it is in that field, because the articles with new and useful ideas are often cited more. Table 4 shows the 10 most cited papers of all time in RSC research.

Table 4. Most influential articles in reverse supply chain research.

Rank	Journal	Article	TC	Author/s	Year	C/Y
1	IJMR	[45]	1503	Srivastava, Samir K.	2007	115.62
2	EJOR	[46]	1028	Fleischmann, M; et al.	1997	44.70
3	MS	[47]	1007	Savaskan, RC; et al.	2004	62.94
4	EJOR	[48]	906	Melo, M. T.; et al.	2009	82.36
5	JOM	[49]	759	Linton, D.; et al.	2007	58.38
6	EJOR	[7]	700	Govindan, K; et al.	2015	140.00
7	JOM	[50]	548	Sarkis, Joseph; et al.	2010	54.80
8	JEM	[51]	534	Ilgin, Ali; Gupta, M.	2010	53.40
9	EJOR	[52]	516	Brandenburg, et al.	2014	86.00
10	IJPE	[53]	481	Hassini, Elkafi; et al.	2012	60.13

TC—Times cited; IJMR—International Journal of Management Reviews; EJOR—European Journal of Operational Research; MS—Management Science; JOM—Journal of Operations Management; JEM—Journal of Environmental Management; IJPE—International Journal of Production Economics.

It is evident from Table 4 that the 2007 paper by Srivastava [45] is the most cited of the search results. Next are the papers by Fleischmann et al. [46] and Savaskan et al. [47], with more than 1000 citations for each. There are several other influential authors, such as the recent paper by Govindan et al. [7], which has the most citations per annum.

Many authors play a key role in RSC research studies. Table 5 presents the 10 most influential authors with the highest number of publications in the field of RSC. Notably, the number of articles published is only an indicative measure, as many other factors need to be considered, such as co-authorship, paper size, and journal quality. Therefore, Table 5 presents the total citations received by each author, H-index, and citations per item. Table 5 shows that Govindan is the most influential author in the field of RSC with more than 4700 citations, followed by Kannan with 1719 citations despite the low number of articles he published, and third is Adenso-Diaz with 1056 citations. Regarding the number of publications, Govindan is also highly ranked with 55 papers published in the field of RSC (Table 5).

Table 5. Most productive and influential authors in the field of reverse supply chain research.

Rank	Name	TP	TC	H	Citations per Paper
1	Govindan K.	55	4794	33	87.16
2	Tavakkoli-M	21	637	11	30.33
3	Gupta S.M.	20	1018	13	50.90
4	Jaber M.Y.	18	771	16	42.83
5	Kumar A.	18	187	8	10.39
6	Diabat A.	17	853	14	50.18
7	Kannan D.	17	1719	14	101.12
8	Mangla S.K.	16	512	10	32.00
9	Adenso-Diaz B.	15	1056	12	70.40
10	Shankar R.	15	815	10	54.33

TP—Total papers published; TC—Times cited; H—*h*-index.

Research related to RL and RSC is conducted at more than 500 institutions. Many of these institutions are popular, and the 10 most influential institutions in the field are presented in Table 6, which is sorted according to the total number of publications (TP). The results of Table 6 reveal that the Indian Institute of Technology System have the most institute TP in the field. However, University of Southern Denmark is most cited institution, whereas Erasmus University Rotterdam has the most rate of citations per item. In this list, three of the institutions are from Iran, and in general 50% institutions are Asian organizations. It is worth noting that only one Canadian institute and one institution from USA have found a place on this list.

Table 6. Most influential institutions in the field of reverse supply chain research.

Rank	Name	Country	H-Index	TP	TC	C/P
1	Indian Institute of Technology System	INDIA	27	80	2664	33.30
2	University of Southern Denmark	DENMARK	38	70	5869	83.84
3	University of Tehran	IRAN	23	58	2653	45.74
4	Islamic Azad University	IRAN	20	53	1396	26.34
5	Iran University Science Technology	IRAN	13	43	627	14.58
6	Erasmus University Rotterdam	NETHERLANDS	27	36	4547	126.31
7	Ryerson University	CANADA	22	32	1730	54.06
8	Aristotle University of Thessaloniki	GREECE	21	29	1444	49.79
9	Hong Kong Polytechnic University	CHINA	16	28	1199	42.82
10	State University System of Florida	USA	13	24	843	35.13

TP—Total papers published; TC—Times cited; C/P—Citations per paper.

3. Reverse Logistic Characteristics and Decision Delineation

Savaskan et al. [47] established three classic analytical models of closed-loop supply chain consisting of three recovery channels: manufacturer, retailer, and third party. This study discusses the collection efficiency of different channels without considering the collection competition from the perspective of the whole supply chain. Figure 5 shows the various aspects of RL considered in this research.

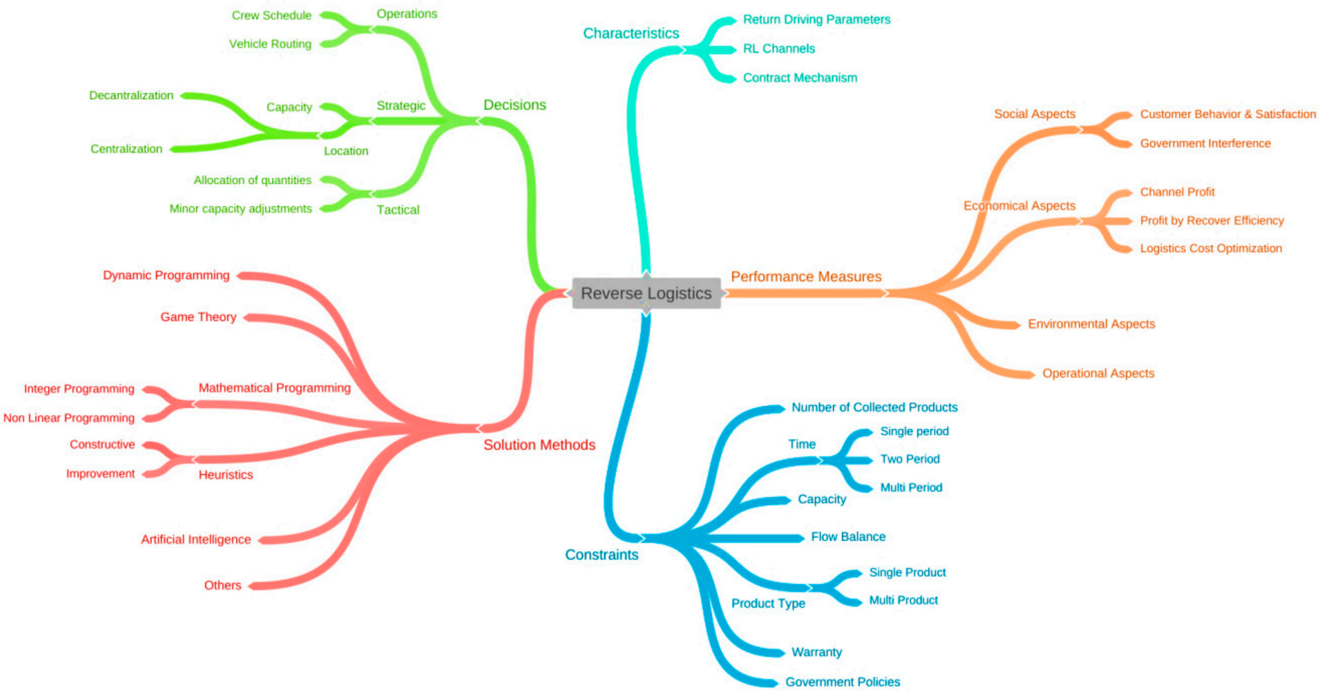

Figure 5. Various reverse logistics aspects considered in this research.

3.1. *Reverse Logistic Characteristics*

3.1.1. Reverse Logistic Channel(s)

One way that RL characteristics can be classified is by looking at the recovery channel, namely the manufacturer, retailer, and third party [47], considering the collection competition between them. He et al. [54] discuss recovery efficiency where the retailer competes with the manufacturer to conduct the collection in a decentralized model. However, it was concluded that the competition between the manufacturer and retailer for collection does not enhance efficiency. Similarly, Wang et al. [55] analyzed competition between two manufacturers that produce substitutable products and the retailer, who was also willing to join the collection if regulations supported it, which is more relevant to the emerging market. It was recommended that the policymaker should inspire the retailer to accept more responsibility for collection. Another channel model study involved the manufacturer and recycler but considered offline and online approaches [56]. It was reported that the implementation of an online recycling channel can often help the remanufacturer, but it can harm the recycler.

Rahmani et al. [57] added a channel, namely a collector or third party, into the reverse chain. They analyzed two chains where the manufacturer from each chain was competing. Under four types of decision making model, namely decentralized, centralized, horizontal cooperation, and coordinated, they found that coordination improved recovery efficiency. Other research that considered the three channels is presented by Taleizadeh et al. [58]. Their analysis considered the centralized and decentralized structure. Along similar lines, Zerang et al. [59] and Wei et al. [60] also considered the analogous structure with three channels. The later article considered the profit discount to analyze the performance of the combination between channels doing a collection process in two period models. They found that the profit discount affects the remanufacturer but not the retailer profit and the collection competition does not generate differences in the individual channel optimal collection rates.

Kushwaha et al. [61] discuss channel selection for the collection process in scattered geographic regions and suggest that it is important to consider the quantity of returned product that can reduce carbon emissions. Wu et al. [62] investigated dual channel RSCs, namely recycling centers (online and offline) and third party recyclers under centralized and decentralized decision making. Cao et al. [63] investigated a bi-level programming model of government and a RSC consisting of one manufacturer and one recycler based on the extended producer responsibility (EPR) principles. They considered the governmental policy formulation to analyze the reactions of the RSC. They suggested that members of the supply chain can be encouraged to pursue environmentally sustainable measures in the context of sound policies, with real remanufacturing rates boosted and recovery efforts improved, thereby strengthening the remanufacturing industry, particularly at an early stage.

3.1.2. Contract Mechanism

Competition in the collection process inhibits efficiency. Therefore, collaboration using a contract mechanism provides a solution. In this mechanism, manufacturers opt out of collection competition and have a contract with the retailer with particular terms and conditions. Some examples of a contract mechanism are revenue sharing, delays in payments, collaborative models, cost-sharing, two-part tariffs, compensation-based wholesale prices, and buy-back. He et al. [54] suggested a two-part tariff contract between channels similar to Rahmani et al. [57]. The proposed contract effectively improves the recovery efficiency. Wu et al. [62] proposed a revenue sharing contract between channels to improve the profit of a decentralized model so that it can reach the minimum profit of the centralized model. Discussion about the contract mechanism often only considers one type of contract (profit sharing). However, there are other contract mechanisms that can perform better for the situation being analyzed.

3.1.3. Return Driving Parameters

The product return rate when it reaches its end of life (EOL) can be stimulated by policy (legislation or economic) or by means of technologies. The policy, such as EPR, increases the duty of manufacturers for after sales services, including take-back, recovery, and disposal [64]. The technology, such as Radio Frequency Identification (RFID), is offered to trace the obsolete product [25] and to classify its quality. The Internet of Things (IoT) that combine with Kanban is another technological driver to signal time and quantity of waste collection [65]. A Kanban is a card-based control system that uses physical cards to signal information. Cards provide basic visual information. Therefore, their applicability in large geographical contexts is very restricted. Henceforth, a framework is presented that combines Kanban with IoT.

3.2. Decision Delineation

Reverse supply chain problems consist of various decisions that need to be considered. There are three levels of decision that are commonly considered in RSC: strategic, tactical, and operational decisions [66]. Strategic decisions include long-term decisions on locations and capacities and technologies of facilities. In the medium-term, the tactical decision includes allocation of production quantities and minor adjustments on capacities. The lowest level, which is operational decisions, cover the setup of vehicle routing plans, short run production volumes, and crew schedules. The following subsections explain the types of decisions described in the reviewed articles (see Table 7).

Table 7. Decision delineation references.

Decision Type	Reference
Center location/allocation	[67–71]
Quality of the returning product	[69,72,73]
Centralization vs. decentralization	[57,58]
Inventory system	[65,68,70,72,74]
Others	[25,68–70,74,75]

3.2.1. Center Location/Allocation and Its Capacity

The center location/allocation decision is usually represented by binary variables to determine whether a facility is opened in a specific region or at a specific moment to expand the capacity of the center. Mishra and Singh [67] determined a hybrid warehouse that can be used for collection and repair. Reddy et al. [68] considered the opening of an inspection center at a specific time to incorporate the holding cost. The new or extended capacity of the collection center is discussed by Park et al. [69]. In another article, Xiao et al. [76] considers the establishment of dismantler facilities for automotive industries.

3.2.2. Quality and Quantity of the Returned Product

The remanufacturers determine the minimum quality and quantity of the EOL products to optimize their profit and follow environmental regulations. Therefore, the collector should adjust their inspection method [69,72]. Wang et al. [73] describe the criteria required to evaluate product quality, such as damage level and remaining service life. Based on the literature, there are two kinds of product returns: defective item return and waste/EOL product return [77]. Therefore, it is important for collection centers or any entity involved in collection to have appropriate quality check mechanisms, and based on that, they can classify the products to different categories, making RLSC more efficient.

3.2.3. Centralization vs. Decentralization

Centralization refers to the number of locations where similar activities are conducted. In a centralized network each activity is only installed at a few locations, whereas in a decentralized network, the same operation is conducted at several different locations in parallel. Thus, centralization could be seen as a measure for the horizontal integration or "width" of a network. Taleizadeh et al. [58] concluded that a centralized structure outperforms a decentralized one in achieving the highest total expected profit, attaining the highest demand by setting the lowest selling price, and also by considering the environmental viewpoint and resource usage. Another article also mentioned that a centralized structure has better profit performance than a decentralized one [57]. The decentralization strategy seems unsuitable for RL. However, this disadvantage can be minimized so that it can reach the minimum level of the centralization benefit [62]. Therefore, most of the literature reported the centralized system as more efficient in terms of profits.

3.2.4. Inventory System

Inventory is one of the contributing costs of a product and it appears on the collection system. It requires consideration from the decision maker to manage the performance of the system. Reddy et al. [68] developed a mathematical model, including the cost of carbon emissions, which incorporated environmental factors, inventory holding time, and transportation. In another article, Reddy et al. [70] considered the quantity of the inventory in an inspection center and also the holding time that affects the cost. Similarly, Zhou et al. [72] included the inventory in the collection center and after the remanufacturing in their model. Additionally, in the selection of take-back pattern, Tian et al. [74] found that the inventory management had a moderate influence on the RL system. Hence, inventory control and management is also considered an important aspect of RL in the literature.

3.2.5. Others

Ullah and Sarkar [25] developed a tracking system using RFID and consider the collection rate of the new system. Tian et al. [74] proposed a method that involves a new member, namely joint liability organizations to do the collection. They concluded that the pattern provides comprehensive performance according to their criteria. Park et al. [69] considered that a specific region is assigned for a collection center to save the transportation cost and enable better information flow. Additionally, the selection of transportation mode to move the product between channels is considered as a decision factor [68,70]. Performing an incentive can also be considered a decision that manages the flow of a returned product [75].

4. Constraints and Performance Measurements

4.1. Constraints

The diversity of constraints that appear in the manuscript have been classified and distinguished between hard and soft constraints for each category, where possible. The categories are capacity/availability, flow balance, time, product type, number of collected products, and warranty constraints (Table 8).

Table 8. Constraints used in RL Modeling.

Constraints	References
Capacity/availability	[67–70,76]
Flow balance constraints	[61,67–70,76]
Time constraints	
Single period	[69]
Two period	[60,78]
Multiperiod	[67,70,72,76]
Product type constraints	
Single product	[68–70]
Multiproduct	[67]
Number of collected products constraints	[61,69]
Warranty constraints	[67]
Government policies	[79–81]

The constraint of capacity is the key characteristic of the collection system. Capacity not only considers the facility [67,69], but it also includes the capacity of the vehicles [68]. An example of capacity constraint is ensuring that enough inventory spaces are available during each time period, whereas the objective function minimizes the inventory through its cost. The flow balance constraints are constraints to ensure balance in the flow of product entering and leaving the adjacent components of a collection system. The products leaving the collection system can be delivered for remanufacturing or disposal [67–69].

The time constraint considers constraints to the period of inventory value. There are three types of the periods: the single period [69] where the models are static because no subsequent data are required, two period [78], or multiperiod [67,70,72,76]. The difference in the last two types is the time horizon where some researchers reported that it is sufficient to test the model by using only two periods instead of utilizing multiple periods. The total time horizons for the two period or multiperiod models normally use weeks, months, or even years.

The product type constraints consist of single product [68,69] or multiproduct [67] constraints. However, the multiproduct model is not necessarily represented by different products because these products can move in the same network link simultaneously [82]. Park et al. [69] added the number of collected product constraints and tried to maximize this to develop remanufacturing policies. Another constraint is the warranty that has been utilized by researchers, such as Mishra and Singh [67]. The return lead time is an important factor that is rarely considered by researchers because it makes the model more complicated.

4.2. Performance Measures

Assessing the performance of RLs is an important factor in managing its strategic, tactical, and operational decisions. However, measurement metric development is not an easy task because of the difficulties in operating and coordinating the flow of materials and information [83]. Therefore, it requires comprehensive knowledge of what has been done in previous research regarding the performance of RLs to obtain insight about gaps and future research. In the next section, we consider four aspects of measuring performance: economic, environmental, social [84], and operational performance.

4.2.1. Economical Aspects

Economic aspects are classified into three more categories and explained in the following subsections.

Logistics Cost Optimization

Logistics cost optimization involves the optimization of the cost of product acquisition, collection, inspection, and transportation. Ullah and Sarkar [25] proposed minimization of the cost of implementation and the design of the RFID-based recovery channel. Xiao [76] considered minimizing the network cost that consists of three components: location cost, transportation cost, and emission cost. Minimizing the inventory cost has also been considered [85]. Park et al. [69] considered the transportation, remanufacturing, and disposal cost. Additionally, Mishra and Singh [67] minimized the total cost that consisted of remanufacturing, inventory, transportation, import/export, depreciation, and repairing.

Profit by Recovery Efficiency

Profit by recovery efficiency refers to the recycling of used products back into useful raw material. Rahmani et al. [57] consider the quality of the remanufactured product as their objective. If the quality of the returned product is good enough, then the recovery efficiency of working parts or useful raw material will be higher. Moreover, recovery efficiency also indirectly has a significant effect on transportation efficiency. Additionally, Zhou and Sun [72] developed a model that maximizes the profit of a hybrid manufacturing-remanufacturing system, and Park et al. [69] redesigned the network considering the quality of the returned product to reduce the remanufacturing cost. Further, Reddy et al. [70] minimized the costs of location setup, operation, inventory, disposal, purchase, transportation, and emission.

Channel Profit

Channel profit is the profit obtained by the collector [57,58] or manufacturer [61]. Wei et al. [60] concluded that the profit discount has no effect on the optimal retail/wholesale prices for the second period and only affects the optimal decisions for the first period. As the profit discount increases, the remanufacturer's profit increases very rapidly, regardless of the remanufacturer's options for collecting used products. The retailer and the third party will make the same optimal collection rate when they jointly collect used products, which means the collection competition does not generate differences in their individual optimal collection rates. Wan et al. [85] analyzed the transfer pricing policies between the channels that maximizes its profit. They concluded that the customer, manufacturer, and retailer will get the benefit using different transfer prices. However, for the sake of the environment and third party, they will get the benefit if the transfer price is uniform.

4.2.2. Environmental Aspects

The costs of the disposal of returned products, which cannot be remanufactured or recycled, to ensure safety and environmental protection are considered in some research [69,86]. Minimization of the fuel consumption of the vehicle fleet and reduction in center emissions are considered as the measuring parameters [61,67,68,76].

Wang et al. [87] researched the e-waste remanufacturing utilization rate and the marginal effect of the subsidy to the remanufacturer in terms of economic benefit and found that the quantity of recycling is directly proportional to the subsidy. Oliveira Neto et al. [88] presented the environmental impacts of RL using a case study of battery collection in Brazil. Their research showed a significant decrease in solid and chemical waste. Additionally, Uriarte-Miranda et al. [89] presented a conceptual model and review of the RL strategy for tire waste in Mexico and Russia. The model included the policies and regulations of each country. Marsillac [90] presented the similarities and overlapping aspects of RLs with a green supply chain. It was reported that the purpose of both concepts is environmental benefits. Therefore, there is some common ground that should be studied in a holistic manner.

Li et al. [91] developed a mixed linear integer programming model for RL to report the environmental and health issues raised due to electrical and electronic waste. They classified the sources into formal and informal sectors and identified opportunities to increase recycling and mitigate environmental impacts. Lau and Wang [92] studied the RLs for electronics product for a case study in China. They reported that the RL strategies vary from organization to organization. Therefore, to reduce the impact of electronics waste on the environment, strict laws and regulations should be implemented by the government. Liu et al. [93] developed a quality-based price model for electrical and electronics waste recycling that included both formal and informal sectors. It was deduced that the government has less control over both formal and informal sectors, and rapid development of electronics product and the amount of waste produced in large proportions pose serious threats to the environment.

Foelster et al. [94] presented the benefits of recycling refrigerators by using a case study in Brazil. They reported that a significant amount of carbon dioxide emissions can be saved by life cycle assessment and recycling of refrigerators. In addition, Guarnieri et al. [95] utilized strategic options development analysis methodology to analyze the RLs of electronics and electrical waste. It was concluded that the RL of electronics waste is important to control environmental degradation. Caiado et al. [96] presented a comparison of the RLs credit market with the carbon credit market. It was reported that for the RL credit market there are no norms and much legal support is required to lessen the burden on the environment.

It was concluded by most of the researchers that RLs has a positive impact on the environment [97–99]. However, most of the research only considered carbon emissions, whereas other pollution elements can affect the environment.

4.2.3. Social Aspects

Banihashemi Taknaz et al. [100] presented an in-depth review of the relationship between RL and sustainability. They reported that there is more of a focus of researcher on economic and environmental performance. However, the social element of RL has been neglected and requires analysis.

Customer Behavior and Satisfaction

Poppelaars et al. [101] investigated the effect of product design on consumer behavior to return the product. Pisitsankkhakarn [102] studied the factors that can improve consumer purchase intention of the remanufactured product, such as quality of the product, product physical appearance, the packaging that explains product knowledge, and the product price. Mohamed et al. [103] studied the effect of RL on customer satisfaction using a real case study of a heavy equipment distributor. They showed that customers had a positive attitude toward RLs and remanufacturing. Jalil et al. [104] studied customer satisfaction in the RLs of e-commerce business or online shopping by using a case study in the Klang Valley of Malaysia. Survey-based approaches were utilized and results indicated that situational factors, such as accessibility and advertising, have a significant impact on customer satisfaction.

Government Interference

A financial incentive, such as incentives to manufacturers [105], collectors [87], retailers [87], or even customers [106], have been implemented in many countries. Government regulations are a major impetus driving remanufacturing [59]. An example of a manufacturer incentive is the take-back laws or TPR (third-party remanufacturers) to manage e-waste [107]. Another policy is the government subsidy to motivate manufacturer collection [78] and remanufacture [85]. An incentive to the customer can avail a subsidy worth 13% of the price of the new item on buying a remanufactured product [108,109]. However, restrictions on the import of remanufactured products by countries, such as India and Brazil, could hamper the popularity of remanufactured products [110]. Besides the incentives, governments can also provide punishments, such as carbon tax, to control the emissions of manufacturing, which can increase the collection rate of the used product to be remanufactured [78].

4.2.4. Operational Aspects

Ullah and Sarkar [25] considered the investment costs of the system and retrieving, shipment, inspection, quality upgrading (remanufacture), and disposal cost. Park et al. [69] also maximized the number of remanufacturing EOL products using inspection quality.

In reviewing the literature on decision making policies, it is noteworthy that most authors develop a multi-objective model, but most of the papers only focus on economic and environmental perspectives, rarely considering the social perspective. The performance measurement is hardly ever presented in a holistic manner rather than one or two perspectives. In addition, there are few studies addressing global business issues.

Table 9 is showing some of the information of the articles that discuss different performance measures.

Table 9. List of articles of performance measurement.

Performance Measurements	References
Economical	
Logistic cost	[25,67,69,76,111]
Recovery efficiency	[57,69,70,72]
Channel profit	[57,58,60,61,85]
Environmental	
Disposal policies	[69]
Emission reduction	[61,67,68,76,112]
Waste reduction	[87]
Social	
Customer behavior	[101,102]
Government interference	[59,78,85,87,105–110]
Operational	[25,69]

5. Solution Method and Uncertainty Incorporation

The literature shows a wide range of research methodologies that combine a certain type of analysis with some solution or evaluation technique. A number of articles are classified into several different categories and are presented in Table 10.

Table 10. List of articles of solution methods.

Solution Methods	References
Mathematical Programming	
Integer programming	[70,113–129]
Nonlinear programming	[67,69]
Heuristic	
Constructive	[113,118,120,130–132]
Improvement	[120,130,131,133–135]
Game theory	[54–57,59,60,62,85,87,136–141]
Artificial intelligence	[26,74,119,142–145]
Dynamic programming	[72]
Others	[73]

Most of the applied approaches fall under the domain of mathematical programming. In these approaches, the RL collection problem is modeled as a linear, integer, mixed integer, or nonlinear program. Metaheuristics form an important class of solution methods used to solve the RL collection problem. Metaheuristics are designed to tackle complex optimization problems where other optimization methods have failed to be effective or efficient. The practical advantage of metaheuristics lies in both their effectiveness and ease of applicability. Their effectiveness depends on the production of reasonably good feasible solutions within a limited amount of running time, whereas mathematical programming techniques run the risk of not returning any feasible solutions for a long time. Researchers tend to prefer metaheuristics approaches for RL problems, such as Tabu search [146], genetic algorithms [147], and simulating annealing algorithms [148]. Game theory is primarily used for determining channel characteristic and the effect of a channel decision [60]. However, using metaheuristics also results in a number of drawbacks, because they cannot demonstrably produce optimal solutions or demonstrably reduce the search space [70].

One classification field that is rarely discussed in any of the reviewed papers is the incorporation of uncertainty. Deterministic location and transportation approaches ignore every form of uncertainty, whereas stochastic approaches try to incorporate it. Trochu et al. [149] presented a RL network design problem solution using mixed integer linear programming. They presented a case study of recycled wood material for the construction industry in Canada. The major contribution of the developed model was the consideration of uncertain factors. In addition, Paduloh et al. [150] presented an in-depth review of the literature for uncertainty models in RSCs, and they reported the most widely used techniques and research aspects.

6. Application Area and Applicability of the Research

This section presents the applications considered as the research focus (Table 11). In the development of a model or a formulation, researchers usually provide a testing phase to illustrate the applicability of their research. The data were distinguished into theoretical and real world data. If it was not clear whether the model was actually implemented, the paper was classified as real world data.

We noticed that in many papers the intervention was only compared with a few other recent interventions, which the researchers had to implement themselves. Usually, they only considered the problem that was the focus of their paper rather than comparing performance to a benchmark.

Table 11. List of articles classified according to application.

Application Area	References
Electronic	
- Mobile phone	[25,144,151]
- Battery	[67,152–155]
- Large appliances (washing machine)	[129]
- Camera	[68]
- General	[156]
Automotive	[74,76,125,157–160]
Furniture	[142,161]
Waste	[65,87,129,133,137]
Liquor manufacturing	[69]
Data set	[61,67,70]

7. Discussion and Conclusions

RL is gaining popularity because it is a driving force for the sustainable development of the supply chain process. It is an important pillar of circular economy, and is grabbing attention of researchers [162]. Some researchers reported that RL is an inseparable part of circular economy, and its success is directly related with the realization of circular economy [163,164]. Henceforth, it is important to study RL for circular economy accomplishment and the relationship between these two is an interesting area for future research. Various aspects of the RL have been explored by the researchers, including economic, social, and environmental aspects. It was inferred by most of the researchers that RL has economic benefits [100,165]. However, some of these aspects differed from this opinion, and it was reported that it does not have significant economic gains [166]. For the social aspects, a significant positive relationship was reported between RL and social performance [167]. However, some of the researchers had contrasting opinions [168]. Thus, there is still substantial scope for further investigation in these two aspects of RL. Based on the literature and the authors understanding, RLs can have a contrasting nature depending on the area or domain of implementation. Hence, further examination is required. In the case of environmental aspects, the majority of researchers reported benefits [97–99] though most of the research studies include carbon emission as a performance measure, and there are various other understudied pollutants and factors that could be considered to obtain a better understanding of RLs. The literature suggests that other factors that are important for RL include inventory management [169], transportation management [170], quality inspection of the returned product [171], and government policies [172]. The collection system is yet another important area that requires in-depth investigation by researchers.

Moreover, different techniques and methods have been implemented to investigate RLs, including mathematical modeling, case studies, qualitative and quantitative methods, and decision support systems [113,118,173–175]. The upcoming research is mostly focused on including uncertain factors in models. Thus, it will make the problem more complex and require further efforts from researchers and contemporary techniques to solve this problem.

In this paper, the literature on RL collection systems was reviewed. Four primary criteria to classify the existing publications were identified. After comprehensive review of the topic, it was revealed that most of the research has measured the economic and environmental performance of the collection system and rarely considered the social aspects of performance. Moreover, research on the combination of all aspects is difficult to find because it makes the research model more complicated. Another finding is that solutions are specific to problems, which cannot be measured objectively, because there is no benchmark to state what method is best. Therefore, it is necessary to build a problem set that can be used to evaluate the solutions. Figure 6 shows future directions of research.

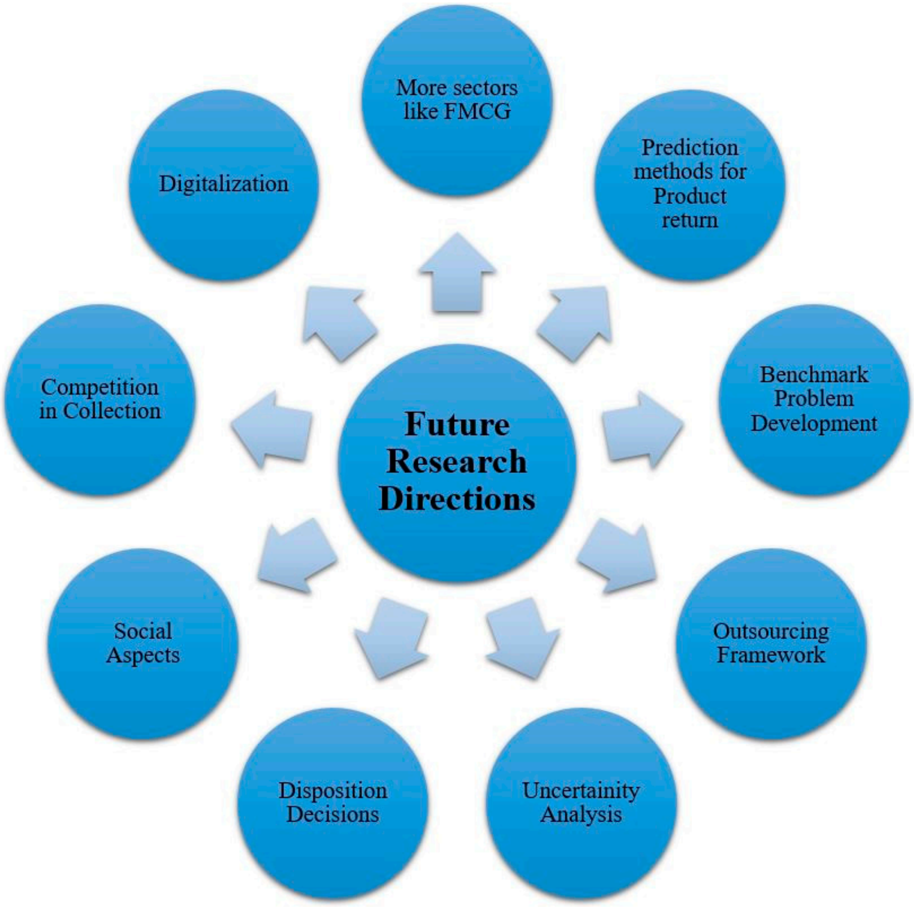

Figure 6. Future directions of reverse supply chain research.

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