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Uncertainty Models in Reverse Supply Chain: A Review

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***Abstract*— Reverse logistic has become an important topic for the organization due to growing environmental concern, government regulation, economic value, and sustainable competitiveness. Uncertainty is one of the key factors in the reverse supply chain that must be controlled; thus, the company could optimize the reverse supply chain function. A total of 76 published articles were selected, analyzed, categorized and the research gaps were found among them. the theme of the paper taken for this research is reverse logistic, close loop supply hain, reverse supply chain and reverse Model. In this study, we explore reseach methodologi, industry and the aspect of uncertainty. We make an analysis uncertainty for the topic, approach, model formulation and make comparison of uncertainty reseach area. The most used approach and method on uncertainty are Mixed Integer Linear Programing, mixed integer nonlinear Programing, Robust Fuzzy Stochastic Programming, and Improved kriging-assisted robust optimization method. Customer demand, total cost, product returns are the most widely researched aspects. This paper may be useful for academicians, researchers and practitioners in learning on reverse logistic and reverse supply chain; therefore, close loop supply chain can be guidance for upcoming researches.**

***Keywords*—** *Reverse Logistic, Reverse Supply Chain, Uncertainty, Model, Review.*

1. Introduction

Reverse logistics (RL) is an activity that includes returning products from customers for the reasons of end of life (EOL), product repairs, product guarantees, or increased consumption of the lease period. Attention to RL activities continues to increase both from researchers, academicians and industry. Economic and environmental backgrounds become the most powerful reasons in the discussion of reverse logistics. Many of the wastes produced, global warming, and continuously used of natural resources, and the need for raw materials for the industry are among important reasons to reverse logistics from the environmental aspect. Government regulations regarding the environment also become a continuous developing discussion and a need for including industry. The pressure to make products that are environmentally friendly and take back unused products makes industrial needs of reverse logistics difficult. Another reason for being obedient to government regulations is that the companies will get an economic value from those EOL products by changing them into different products, reusing, recycling, and adding a value of these products as raw used materials [1].

The research activities carried out are researches on the environment related to reverse logistics [2], the factors influencing the environmental sustainability i.e. customer perspective, and information and environmental sustainability issues in the logistics service provider industry [3], research for cases in beverage industries, and researches focusing on the environmental issues as the background of research [4] [5]–[9] [10]–[13]. In this study theme of the environment and government regulations encouraged many companies to carry out reverse supply chain activities. These conditions also urge research development themes about reverse supply chains.

Research on reverse supply chain is also divided into more specific issues such as close loop supply chain [2], [14] [13] [15] [16] [17], Reverse Logistic [3] [18]–[22] [23], [24], [25], [26]–[28],[29], [30], and Reverse supply Chain [31] [32] [6]. In addition, the methods used to solve cases in reverse logistics vary [33]–[35]. It uses MILP approach in completing the case, [2], [25][13], as well as MINLP, RFSP approach [36], MCDM [23], [37], [38]. Other approaches used by researchers are Deterministic, MADM, K-RMO to resolve existing cases. Related to the method of uncertainty, 60% of the researchers discuss the Close Loop Supply Chain, 10% discuss Reverse Logistics, 10% discuss the Reverse Supply Chain, and 10% discuss Reverse method.

Uncertainty in reverse supply chain, a mathematic approach like robust optimization, stochastic, deterministic and hybrid are common methods to solve the cases of reverse supply chain. Studies related to this topic were conducted by [2] discussing Total Cost, Demand, Returns Prod, Transportation, and Price for scope uncertainty, [36] discusses Cost, Capacity, and Demand. [39] discusses

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Cost, Risk, Return Product, and Material. [34] discusses Minimum total Cost, operation, facilities, capacity, and material flow. [13] discusses Cost Transportation and Customer Demand. [40] discusses Quality of Return Product and remanufacturing Capacity. [41] discusses Production Planning due to Customer Demand and Collector. [42] discusses Facility Location, Environment Fluctuation, and Market Competitiveness. [8] discusses function for Production Plant, Distribution Center, Disposal Center, Market Zone and [43] discusses Facility Location.

State of the art from this study is analyze, synthesize and compare reverse supply chain research in uncertainty for methods, areas of discussion, approaches, formulations and supply chain models in the reverse supply chain in uncertainty model. The objective of this study is to give references to further research and a reference to later research. Uncertainty is an interesting topic to discuss since, in reverse supply chain, uncertainty is an important aspect for consideration that will give impact to reduce total costs and finally give impact to increase economic and environmental growth.

2. Literature Review

Firstly, this study discusses previous research on Reverse Supply Chain, Reverse Logistics and Close Loop Supply Chain through Google scholar and Literature review to identify the conceptual and guides toward the theory development content of the research area. In order to systematically review the literature and clarify research methodology, four steps are taken namely Literature collection and Content Evaluation, Literature analysis and category selection.

2.1 Literature Collection and Content Evaluation

From the search results of Reverse Logistic, Close Loop Supply Chain and Reverse Supply Chain, researchers make a summary of the collected papers and divided them into several parts such as the method used, Industry, Area and conclusions. For the summary of previous researches can be seen in Table 1 below:

2.2 Literature Analysis

Table 1 shows that the most discussed industries are General Industry of 37%, Manufacture Industry of 24%, Retail and Supermarket Industry of 16%, electronics and wood processing are included in the manufacturing industry, agroindustry of 5%, food and beverage industry of 5%. Meanwhile, other industries such as automotive, fashion, contraction, oil and agriculture was 3%, respectively.

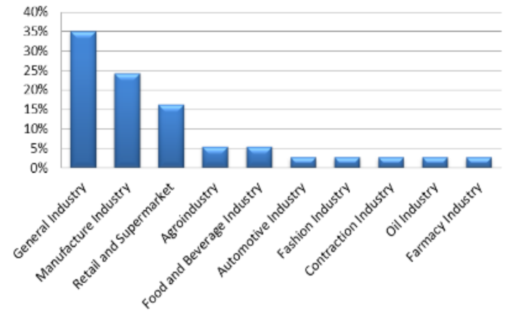

Figure 1. Reverse Logistic Industry Area

Environmental factors become the most common factors for conducting research on the reverse supply chain, besides the need to get economic value by optimizing all the resources within the company and the environment is also the basis for conducting research. They want to reduce cost by providing added value of product returns and unused products [10], [20], [44]–[48], increasing customer satisfaction [10], [25], [49], and controlling product returns. In addition, identification of product returns is also the reason of research on reverse supply chains.

Decision making techniques to decrease costs and risks [17], [35], [39], [45], [50]–[54], then Optimizing supply chains [55], [32], [56], [40], [42], [57] increasing competitiveness [10], [20], [44]–[48], making sustainability strategies a topic that is widely studied, with the aim of avoiding shortages, excess and lack of remanufacturing capacity, and enforcing corporate profits.

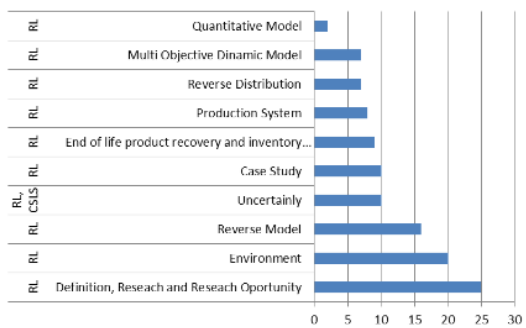

Figure 2. Reverse Topic

Figure 2 shows research topic for Reverse Supply chain, Reverse Logistic and Close loop supply chain. These researches talk about definition, research, and research opportunity, environment, research model, uncertainty, case study, end of life product recovery, production system, reverse distribution, Multi Objective method and Quantitative model. The most common research is about opportunity, environment, reverse model and uncertainty. Meanwhile, this study will discuss uncertainty in reverse logistic, uncertainty factor, approach, area, and software used to solve a problem in reverse logistic.

Table 1. Summary Of Reverse Logistics

Author	Method	Industry	Area	Conclusion
[4]	Survey 200 participants.	Food Product	Customer and Food Product Life Cycle	Customer expectations are more significant in the growth and development phase.
[24]	Green Orientation Strategy	3PL	Focus on Green based on innovation, supervision, and reputation.	Make an effective strategy for defining company positioning
[38]	multi-criteria decision making (MCDM)	plastic recycling firm	Various related functions in RL.	Good inventory management will have a significant effect on RL.
[3]	The questionnaire, Descriptive Analysis.	Food and Beverage Industry in Malaysia	Organizations that face inside and outside challenges.	The interesting factor in RL: *Why-Returned*, *Why-Received*, *What How* and *Who*
[15]	Review of 382 Journals published in 2007 - 2013	General Industry	environmental, legal, social, and economic factors, reverse logistics	Resource Commitment to increase effectiveness and efficiency
[14]	Review of 54 Papers.	General Industry	Multiple perspectives such as company, society, government, and customer.	The company must make a comprehensive strategy.
[58]	NRS, TOPSIS, and VIKOR	3PRLP (third reverse logistic parties)	Decision making in reverse logistics management.	NRS was also used to investigate the resistance of the solution using the multi-stage methodology
[41]	deterministic mixed-integer optimization model and robust counterparts	Fashion Industry	Uncertainty of recycled products and customer demand.	Simulation results show that the recommended model for responding to Robbust is uncertain and superior to other deterministic and deterministic models.
[34]	MILP	construction, renovation, and demolition (CRD) industry	Determining the location and capacity to decrease the amount of wood waste.	Accurate information about the location of sources of supply and the amount of wood is expected to recover from sorting facilities that will ensure the re-design of more efficient RLN
[19]	Wupertal Method	Grocery retailer.	Analyzing the amount of waste generated by each department in Grocery.	good activity leads to improvement towards green regulation.
[59]	Questioner	Oil company	End of life	The company has carried out the principle of Reverse Logistics
[60]	three game theoretic models for two different scenarios with different pricing strategies	manufacturer-retailer	Retailer's responsibility of RL for recycling and remanufacturing.	The results show that stakeholders make better pricing decisions and cooperation.
[47]	selection by using fuzzy SWARA and developed fuzzy COPRAS, multiple attribute decision making (MADM)	third-party reverse logistics providers (3PRLPs), Automotive Industry	The continuous 3PRLPs election in the presence of risk factors	research shows that environmental and social drivers increasingly become dominant when choosing 3PRLPs.
[61]	contingent valuation and conjoint analysis (CA)	Supermarket	food attributes such as brand, price, promotion, and safety assurance, influence consumers' decisions.	Halal food product Certificate was the most important attribute.
[22]	Qualitative Analysis.	Supermarket	changes in purchasing habits, consumers focus on value, convenience, variety, and a better shopping experience	Reverse logistics, electronic point of sale data collection and management of 3PL and 4PL supply chain are becoming increasingly important for the supermarket industry.
[62]	Expert. Simulation SIMUL8, design science research (DSR).	Poultry Industry Bangladesh	Develop a sustainable RSC Model. Issue of environmental impacts and benefits.	Research focuses on sustainable RL for the poultry industry in Bangladesh.
[63]	RFID, Pareto, decision-making algorithm.	Meat in Supermarket.	Detect Security Meat supply chains in supermarkets	Cost effective approach to RFID-based optimization for the SC to seek trade-off for three conflicting criteria and algorithms for multi-criteria decision.
[64]	stochastic remanufacturing capacity, Deterministic Model,	Remanufacturing of Lenovo Group Ltd.	Create a scenario about uncertainly Manufacturing.	Scheme shows the numerical mathematical model of the reciprocal remanufacturing wherein if the number of large refunds the amount paid smaller bonuses.
[31]	Two-stage stochastic multi-objective model.	General Industry	The Distribution Centers (DCs), Customer Zones (CZs) and Recover Centers (RCs) in the framework.	Metaheuristic tri-level is an effective approach to resolve the tri-level models underlying large-scale networks.
[12]	synthesize and analyze the findings based on 112 papers	General Industry	Market segmentation, customer behavior, product design, and the company's network of distributors.	RSC can improve corporate financial performance and contingency factors determine whether RSC operations will be financially feasible if implemented.
[48]	Model description and hypotheses. Mathematic model.	Wood Processing Residue	The model was applied in the case studies where sawdust was recycled to produce black fungus.	The results show effective supply chain coordination.

[40]	Two-stage	Manufacture Industry	Uncertainty in Quality Product Return and Remanufacture Capacity.	An adjusted revenue sharing mechanism is developed to share the risk of uncertainty between two members, fairly.
[65]	Multi-objective mathematical modeling.	a case study in a high-tech industry	The model contains three levels of suppliers, producer, consumers and a center for reconstruction, repair, and maintenance.	the optimum value of decision variables can be determined as the outputs of the model.
[2]	model mixed-integer nonlinear programming (MINLP)	General Industry	Uncertainty Model in periodic demand, raw material cost, transportation cost of material and goods, shortage cost, and the number of return products.	The computing time provided by the proposed algorithm and the right solution is an effective method for high-quality performance of the computing time applied.
[42]	Fuzzy mixed-integer linear programming model.	General Industry	Uncertain factors such as the number of customer product requests, the number of recycled used products and the cost of opening the facility.	Based on the fuzzy approach TH, it obtains a balanced compromise solution that is more efficient than another fuzzy approach.
[36]	fuzzy stochastic		Design of closed-loop supply chain networks under hybrid uncertainty and future scenarios.	The theory may be used to choose the solution in such matters and the proposed fuzzy stochastic programming approach has the advantage of strong significance.
[16]	Mixed-integer nonlinear program- Ming (MINLP).	General Industry	Propose a location/allocation model for multi-echelon multi-product CLSC network, products under shortages, uncertainties, and raw material purchase discounts.	A novel optimization algorithm whale (WOA) aimed at minimizing the total network costs with the application of a modified priority-based encoding procedure is proposed.
[8]	Robust optimization (RO) approach.	Manufacture Industry	Transportation and Distribution Problem.	The topology obtained from integrated treatment of risk and uncertainty is referred to the RORU model, outperforming other supply chain networks on various network performance indicators.
[5]	Two-stage stochastic multi-objective model.	Pharmacy	The environmental aspects and downside risk, simultaneously. number of mimetic	Shows the importance of controlling uncertainty to improve the environmental and economic aspects of CLSC through industry examples.
[11]	Content-based literature review methodology, 45 studies selected.	General Industry	Interpretation of logistics innovation.	This study is one of the first papers on the conceptual development of logistics innovation in China, providing a model for innovation in this context.
[43]	Kriging metamodelling, Robust optimization formulation, reverse model (K-RMRO)	General Industry	Obtain optimal solutions and are relatively insensitive to uncertainty factors.	The proposed criteria based on strong individual status can be changed or not due to the uncertainty of the metamodel kriging interpolation demonstrate proper application and efficiency
[66]	Model Conceptualization, Model Formulation.	Agro product.	Improve environmental efficiency by considering related agricultural wastes that flow to bioenergy companies for energy production.	The first two scenarios assume that all waste flows to the company, while the second is agricultural waste produced by farmers and the wholesale market
[67]	Analytical hierarchy process (AHP) algorithm, TOPSIS algorithm.	General Industry	Supplier Selection, Green Development, Supply Chain Resilience.	Studies to build endurance while pursuing supply chain responsibility 'go green'.
[35]	Mathematics Model.	Car Recycling	Reverse logistics optimization analysis, external costs in reverse logistics cost accounting.	proposals enable companies to optimize the cost and achieve development targets.
[39]	Hybrid Method	General Industry	Model decision-makers to avoid risk and risk-seeking.	Comparison of results shows that minimizing costs does not have a direct relationship with the type of decision maker.
[68]	RL	Cold Chain Logistics	The strategy to develop value-added services from the cold chain between the two countries proposed	Value-added service mechanisms from cold chain logistics, and focus on developing value-added services in both countries.
[25]	mixed integer nonlinear programming model (MINLP)	recycling bulk waste in Taoyuan City	Maximize total profits by handling returned products for repairs, remanufacturing, recycling, reusing, or burning/stockpiling.	Analysis and comparison of post-optimality indicate that the proposed model performs better than the current reverse logistics operations and the proposed hybrid GA demonstrate the efficiency of solving complex reverse logistics.
[51]	Assessments	Waste	The shortest path to maintenance facilities.	Detailed analysis including heat and electricity needs, including social and global environmental criteria. Direct local consequences also play an important role and should be checked.
[69]	Quantitative case analysis	General Industry	Combination of SCM and RL	The RL theory used to identify factors determines the most beneficial relationship between forwarding and backwarding logistics.
[7]	Expert Interview	Electronic Industry.	Identifying the contribution of increased reverse logistics.	Reverse logistics increase the potential for reusing and efficient resource recovery.
[10]	Literature Study.	Retail Industry	Strategic reverse logistics can be used by managers to increase customer satisfaction and manage retail returns.	important implications for managers in managing logistics activities by emphasizing the potential for profit enterprises to reduce costs and add value to the customer
[27]	AHP and fuzzy comprehensive evaluation method	General Company	evaluation index system for enterprises	Flexible capability in the company can solve by fuzzy comprehensive evaluation method and AHP
[26]	descriptive, mean ranking, chi-square, and	Food Retail Industry	investigate reverse logistics adoption by retailers	The results highlight the scenario of reverse logistics adoption benefits obtained and barriers.

	binary logistic regression analysis			
[70]	Sensor-embedded products (SEPs)	Manufacture Industry	Warranty and Maintainability for facility of remanufactured Products	Quantitative assessment effects of offering warranties on remanufactured items and able to determine the optimal costs.
[71]	Literature review	Pharmaceutica l Industry	Market Perception of return product	The perception has shown less enthusiasm

2.3 Frame Work Study

To get a conclusion in reverse logistic model, we categorized the theme of previous researches in Reverse logistic into Reverse Supply Chain, Reverse Logistic and Close Loop Supply Chain. After that, we classified into five categories, namely a method, area, approach, Software application, and Scope or factor The categorization can be seen in Figure 2.3 below:

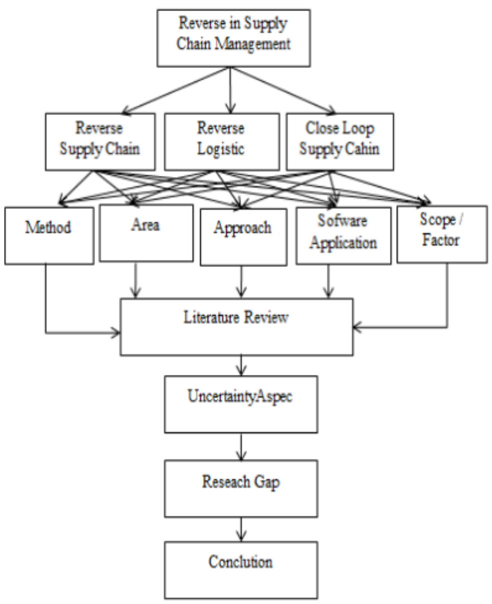

Figure 3. Framework of the Study

2.4 Previous Literature Review

To find out the research theme that has been reviewed; they were summarized. From the Google Scholar, we got 10 journals related to the reverse logistics theme. The summary of journal review can be seen in Table 2 below.

From Table 2, we divide the area that was discussed earlier. As illustrated in Figure 4, Reverse logistics is the most widely discussed theme with dispersion researchers of 50%, a theme that combines the Reverse Logistics and Close loop supply chain of 20%, a theme discussed Reverse Supply chain of 10%, Reverse Logistic and waste Management of 10% and Logistic innovation of 10%. When it is combined as a whole reviewed journals that discuss about reverse logistics, it is 80%.

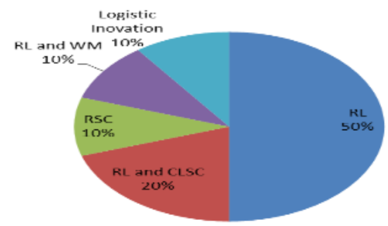

Figure 4. Percentage Of History Research Review

Furthermore, Figure 5 shows that most researches review the operational aspect which includes environmental, legal, social, economic factor, market, product returns with a total of 30%. For the method aspect, the same portions are 30%. In addition, the review conducted by previous researchers did a comparison and find a research gap. Review of technology and financial performance to reverse is 10%. As for uncertainty is one aspect that has not been specifically reviewed and detailed, the next study will discuss research review of the reverse supply chain or reverse logistics from the aspect of uncertainty.

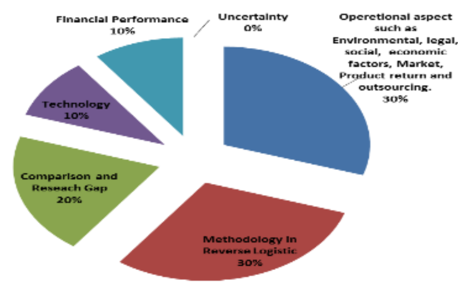

Figure 5. Topic Review

3. Uncertainty Analysis

To consider aspects of uncertainty in reverse logistics, researchers collected literatures related to Close loop supply chains, reverse logistics and reverse supply chains. The Journals is collected by taking advantages of Google Scholar. Some journals that discussed about uncertainty of the three themes are more than10 research journals.

In the Reverse supply chain, [39] says that the reverse supply chain will always be faced with uncertainty. [42] includes demand, use of products, capacity, and facilities in uncertain factors, while costs are responsive and is providing entry into the objective function. In his research, with research taken from 2005 to 2018, the solutions used by researchers were fuzzy programming, scenario optimization, robust optimization, and fuzzy optimization. [41] conducted a study to develop a closed-loop supply chain planning model considering reversing the logistical flow of material uncertainty collected and the uncertainty of demand to discuss environmental problems.

[34] conducted research on the design of reverse logistics networks (RLN) related to industrial environmental policy aiming to make efficient use of raw materials. It uses a mixed linear programming model (MILP) to increase total costs. Facility efficiency and scale of efficiency make targets better than government regulations. The uncertainty of this study is the source. [8] states that Close Supply Chain Network Design (CL-SCND) is an important economic and environmental activity. Activities carried out by closing the loop to ask product freedom include deciding favor of the business environment, supply chain risk, with long-term targets. This study considers design to solve resolution problems. The subject of this study is direct delivery of customers from the factory, distribution is carried out directly through the center, transportation, and requests that did not need to use robust optimization (RO). [33] Research for e-recycling network reverse logistics (RLN) in uncertainty. In this research, the researcher got parameter to increase productivity.

Table 2. Journal Review: Reverse Logistics and Closed Loop Supply Chain

Paper	Area	Scope	Year	Number of Paper
[15]	RL and CLSC	Environmental, legal, social, and economic factors.	2007 – 2013	382 Papers
[45]	RL	Forecasting product returns, outsourcing, RL networks from a secondary market perspective.	1986 – 2015	242 papers
[23]	RL	Finding a method that commonly used in RL, The Multi-criteria decision-making (MCDM) methods are limited.	1990 – 2104	80 Papers
[20]	RL	Comparison of Reverse Logistics with forwarding Logistics.	1995-2009	115 Paper, 28 papers are Selected.
[72]	RL	Methodology for sustainability RL for selection Modeling, Multi-Stage, Multi-Method, Multi Criteria. Third-party reverse logistics provider (3PRLP).	2000-2014	46 Papers
[17]	RL and CLSC	Journal of Cleaner Production (JCP) Research Gap.	2001 – 2014	83 Papers
[14]	RL	Barriers and drivers	1997 – 2107	54 Papers
[12]	Reverse Supply Chain	Firm's financial performance.	2004 – 2017	112 papers
[32]	RL and WM	Environmental, social and performance indicators in multi-objective models	1995 – 2017	207 Papers
[11]	Logistic Innovation	Interpretation of logistics innovation, Technology, RFID, Green Logistic, Reverse Logistic, IT and Cloud Computing.	2002 – 2016	EBSCO 430, SCOPUS 526 Paper, Selected 45 Paper
[73]	RL	the pillars of supply chain management such as sourcing, design, production, packaging, transportation, and consumption.	2001 – 2015	77 Paper
[74]	RL	Model and Issues	1980 – 2012	-

Literatures obtained by researchers is divided into sections of researchers, years of publication and research titles. Next is the CLSC, RSC or RL research area. The formulation, the model and approach are used to solve the problem. The researcher also included the software used for the application of the formulation made. The most important in this section is what factors are the focus on previous researchers. For further explanation, see Table 6.

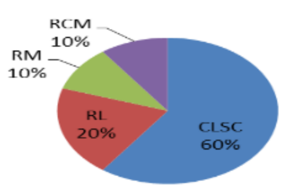

Figure 6. Topic of Uncertainty

Figure 6 shows that theme for uncertainty and Close Loop Supply Chain are the most widely used approaches in which as many as 60% of researchers focused on those topics. Reverse Logistics is 20 %, reverse supply chain is 10 %, and 10% reverse Model.

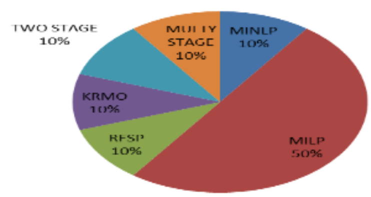

Figure 7. Approach in Uncertainty Reverse Logistic Method

Figure 7 shows that the most widely used method of resolving uncertainty is Mixed Integer Linear Programing (MILP), in which 50% of researchers used this approach. Furthermore, the mixed integer nonlinear Programing (MINLP) was used by 10 %, (RFSP). Robbust Fuzzy Stochastic Programming was used by 10%, Improved kriging-assisted robust optimization method was based on a reverse model of (IK-RMRO) by 10% and multi stage of 10%. Trial software for formulation used WOA, GAMS 23.5 with CPLEX 12.2, AIMMS With Cplex 12.6, GAMS and MATLAB, LINGO 11.0 and MATLAB only. The popular software available is GAMS and MATLAB.

Overall, the research that mostly discusses the uncertainty of a reverse supply chain is the Closed Loop Supply chain model by using a mixed integer linear programming approach. In reverse logistics, there are two types of flows, namely closed loop and open loop or closed loop supply chain and open loop supply chain. The characteristic of a closed loop is if the reverse logistics flow meets again with the original supply chain forward flow, the open loop flow is a reverse logistics flow that is not directly met with the previous forward logistics flow. Closed loop flows occur due to remanufacture activities. In RL activities, the process of retrieving EOL or end of use products from consumers to carry out the recovery process for these products, the material flow then returns to the forward logistics stream. Open loop flows occur when RL activities are carried out by parties of the company, where the company is involved in taking and handling EOL products or informal lines, and the flow in this context does not return to the original forward logistics flow.

Table 3. Uncertanty model formulation and factor

Author and Tittle of paper	Area	Model Formulation	Robust				Trial Software	Uncertainty Factor
			F	H	O	S		
[2] A robust fuzzy mathematical programming model for the closed-loop supply chain network design and a whale optimization solution algorithm.	CLSC	MINLP	√				-	Total Cost, Demand, Returns Prod, Transportation, Price.
[36] A novel robust fuzzy stochastic programming for closed loop supply chain network design under hybrid uncertainty.	CLSN	RFSP				√	GAMS 23.5 / CPLEX 12.2	Cost, Capacity, Demand.
[8] Closed-loop supply chain network design and modeling under risks and demand uncertainty: an integrated robust optimization approach.	CLSC N	MILP			√		AIMMS With Cplex 12.6	Production Plant, Distribution Center, Disposal Center, Market Zone.
[39] Modeling risk and uncertainty in designing reverse logistics problem.	RL	Multi Product Network Design		√			GAMS, MATLAB	Cost, Risk, Return Product, Material.
[43] A kriging metamodel-assisted robust optimization method based on a reverse model.	RM	K-RMRO			√		MATLAB	Interval and Interpolation uncertainty.
[34] Reverse logistics network redesign under uncertainty for wood waste in the CRD industry.	RL	MILP						Total Cost Recycling by sorting centers operation, facilities relocation, capacity expansion, and material flow decisions.
[40] A revenue sharing contract for reverse supply chain coordination under the stochastic quality of returned products and uncertain remanufacturing capacity	RSC	Two Stage				√		Quality of Return Product and remanufacturing Capacity.
[41] A robust optimization model for closed-loop supply chain planning under reverse logistics flow and demand uncertainty	CLSC	Deterministic MILP				√		Production Planning due to Customer Demand and Collector.
[42] Comparisons of interactive fuzzy programming approaches for closed-loop supply chain network design under uncertainty	CLSC	Fuzzy MILP	√				LINGO 11.0	Facility Location, Environment Fluctuation, Market Competitiveness.
[13] A robust optimization approach to closed-loop supply chain network design under uncertainty	CLSC	Deterministic MILP			√		ILOG CPLEX 10.1	Customer Demand and Transportation Cost
[75] Proposal of a stochastic programming model for reverse logistics network design under uncertainties	RL	Two-Stage Stochastic Programming				√	GAMS 21.6/CPLE X 6.0.	return quantity and quality to minimize the total cost
[76] Reverse logistics network design for product recovery and remanufacturing	RL	MINLP			√		GA and CPLEX	remanufacturing, recycling, reuse or landfill

Notes: Fuzzy (F), Hybrid (H), Optimization (O), Stochastic (S).

4. Uncertainty Area

For in-depth research on reverse logistics in Table 4, we break down all factors used. This factor is the theme of previous research to formulate, optimize, improve, correct problems in reverse logistics.

The factors discussed on the research (Ghahremani-Nahr et al., 2019) are Total Cost, Demand, Returns Prod, Transportation, Price. Farrokh et al. (2018) discuss aspects of Cost and Capacity, Demand. Nazari Gooran et al. (2018) discuss Cost, Risk, Return Product, Material factors. Trochu et al. (2018) discuss Total Cost, Operation, facilities, capacity, and material flow. Pishvaee et al. (2011) discusses Cost Transportation and Customer Demand, while Heydari & Ghasemi (2018) discuss Quality of Return Product and remanufacturing Capacity. In addition, Kim et al. (2018) discuss Production Planning due to Customer Demand and Collector And Wu et al. (2018) discuss Facility Location, Environment Fluctuation, Market Competitiveness. At last, Prakash et al. (2018) discuss Production Plant, Distribution Center, Disposal Center, Market Zone and H. Zhou et al. (2018) discuss Facility Location.

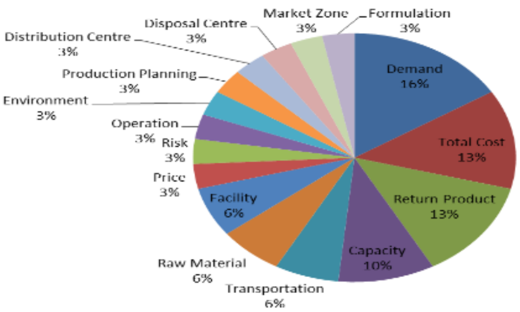

Figure 8. Uncertainty Research Area

The most discussed aspect of uncertainty is customer demand of 16%, total cost, product return is the second most factor discussed of 13%, capacity factor of 10%, then transportation and raw material factors of 6%, price factor, risk, operation, production planning, distribution center, environment, market zone, and distribution center are other factors discussed by researchers, i.e. 3%.

Table 4. Comparison of Uncertainty Research Area

Author	Uncertainty research Area																
	TC	D	RP	Tr	P	C	R	RM	O	F	E	PP	DC	DS	MZ	FL	Q
(Ghahremani-Nahr et al. 2019)	√	√	√	√	√												
(Farrokh et al. 2018	√	√				√											
(Nazari Gooran et al. 2018)	√		√				√	√									
(Trochu e□ al.□2018)	√					√		√	√	√							
(Pishvaee et al. 2011)		√		√													
(Heydari & Ghasemi 2018)			√			√											
(Kim et al. 2018)		√	√														
(Wu et al. 2018)		√								√	√						
(Prakash et al. 2018)												√	√	√	√		
(H. Zhou et al. 2011□)																√	
(H. Salema et al. 2007)			√														√
(Ayvaz, B.a, and Bolat, B.b 2014)		√		√		√		√									

Notes: Total Cost (TC), Demand (D), Returns Prod (RP), Transportation (Tr), Price (P), Capacity (C), Risk (R), Raw Material (RM), Operation (O), Facilities (F), Environment (E), Production Plant (PP), Distribution Center (DC), Disposal Centre (DS), Marker Zone (MZ), Facility Location (FL), Quality (Q).

5. Research Gap

Based on the literature review on categorized issues for the study, research gaps were identified and analyzed by the researchers. Summary of the findings and research gaps are discussed in following subsections.

5.1 Adoption and Implementation of Uncertainty Model

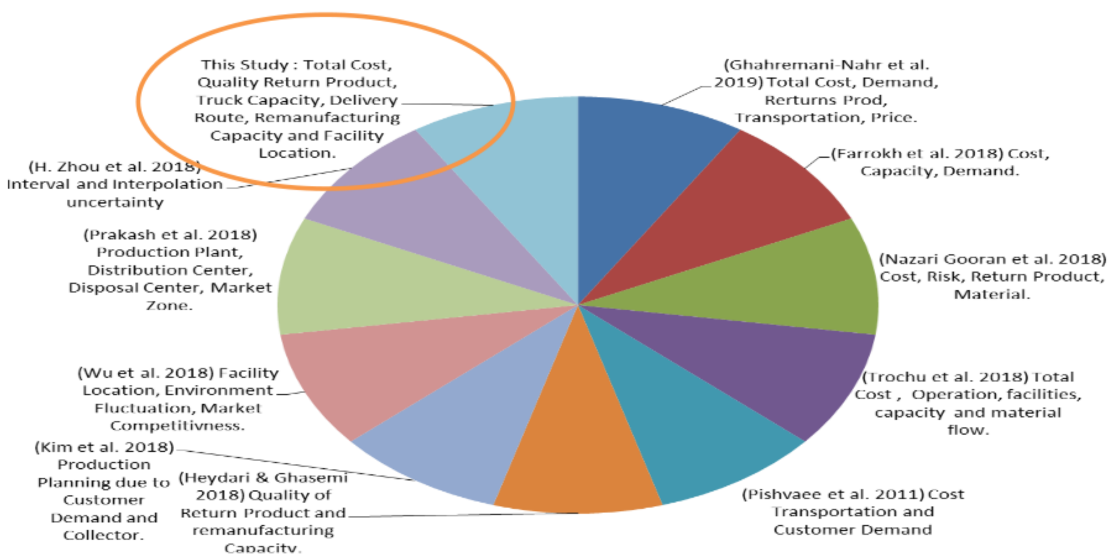

Figure 9. Gap Research

Adoption and implementation of Reverse Supply chain give a big impact in environmental aspect and economic aspect. Researches for both topics are numerous and can provide input on how to increase added value, optimize function, minimize total cost, decrease return product, optimum capacity, and risk. The combinations of previous research are the total cost, demand, returns production, and price [2]; capacity and demand [36]; cost, risk, return product and material [39]; total cost, operation, facilities, capacity and material flow [34]. For the later study, we can combine total cost, quality return product, truck capacity, delivery route, remanufacturing capacity and facility location.

5.2 Method and Approach of Uncertainty Model

Method and approach used in reverse supply chain for uncertainty aspect are Integer Linear Programming (MILP), mixed integer nonlinear Programming (MINLP), Robust Fuzzy Stochastic Programming (RFSP) and Improved kriging-assisted robust optimization method based on a reverse model of (IK-RMRO). Robust functions used for uncertainty topic are Fuzzy, Hybrid, Optimization, and Stochastic. Opportunity for further study is the more in-depth discussion for MINLP, RFSP and IK-RMRO which is still little discussed by researchers.

6. Conclusion

In this paper the most discussed themes of reverse logistic for the background research are environmental and economic aspects. Most of researches discuss definition, research opportunity, environment, research model, uncertainty, case study, end of life product recovery, production system, reverse distribution, Multi Objective method, and quantitative model. In Journal review, Reverse logistics is the most widely discussed theme, followed by the combination of Reverse Logistics and Close loop supply chain, and Reverse Supply chain. The last themes are Reverse Logistic, waste management, and Logistic innovation.

For the theme of uncertainty, Close Loop Supply Chain (CLSN) is the most widely used approach followed by reverse logistics, reverse supply chain and reverse Model. The approach and method used to solve the problem at uncertainty are Mixed Integer Linear Programing (MILP), (MINLP) mixed integer nonlinear Programing, (RFSP) Robbust Fuzzy Stochastic Programming, Improved kriging-assisted robust optimization method based on a reverse model of (IK-RMRO).

The most discussed aspects in uncertainty are customer demand, total cost, product return is the second most factor discussed, capacity factor, transportation and raw material factors, price factor, risk, operation, production planning, distribution center, environment, market zone, and distribution center.

Research opportunity for reverse supply chain based on this research combines total cost, quality return product, truck capacity, delivery route, remanufacturing capacity and facility location got optimum function in uncertainty. The method and approach for MINLP, IK-MRO and RSFP provide many opportunities for research. For theme and area in reverse logistic, both open loop supply chain and close loop supply chain provide the most research opportunities.

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