Optimisation Models of Remanufacturing Uncertainties in Closed Loop Supply Chains—A Review

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ABSTRACT The consideration of uncertainty in closed loop supply chains (CLSC) is a crucial aspect that has been discussed frequently in recent research. Despite a wealth of literature on CLSC modelling, a recent comprehensive review of remanufacturing models in CLSC incorporating an analysis of uncertainty trends has yet to be undertaken. The primary purpose of this paper is to analyse and review the existing research streams encompassing mathematical modelling and optimisation of remanufacturing systems in the CLSC, specifically in the context of decision-making methods. This paper focuses on reviewing remanufacturing uncertainty such as demand, inventory, cost, return yield, as well as the environment and seeks to clarify solutions to problems, including production planning, network design, channel coordination, contract, pricing, supplier selection, and inventory management for the past eight years. A total of 118 research articles were analysed to discover trends on problems, uncertainty categories, mathematical modelling techniques, and solution approaches, as well as providing research gaps and potential future extensions for researchers of common interest. Results from the analysis show that network design and production planning are the most frequent problems considered by previous authors, while analysis of demand and return yield uncertainties in the remanufacturing cycle are the most preferred studies. Finally, limitations and future research needs for decision-support methods in CLSC were identified such that risk domains can be further explored.

INDEX TERMS Closed loop supply chain, review, remanufacturing, uncertainty

I. INTRODUCTION

In recent years, the importance of supply chain management has increased along with environmental conditions and social concerns. CLSC and reverse supply chain (RSC) management are one of today’s global sustainability efforts to preserve the environment [1]. CLSC by Guide et al. [2] is described as the operation of the entire cyclic system, from raw materials processed to the end product, and further when the returned product is recovered or sent to disposal sites. A CLSC can also be considered as a simultaneous forward and reverse supply chain network [2][3]. This process can be demonstrated in Fig. 1 [4], where the dashed line represents the reverse loop (RL), described by four actions namely recycle, repair, disposal and remanufacturing.

Remanufacturing is a process in RSC that disassembles used and newly manufactured products. It is well known for its effectiveness in closing the loop on materials flow, reducing production waste, extending the product life-cycle, saving energy and reducing production costs [5][6]. However, manufacturers are aware of complications with
remanufacturing because the process is more complicated compared to normal manufacturing. According to recent research, remanufacturers struggle to distribute fast and efficient end-of-life (EOL) solutions to fulfill the demand of the market [7][8]. The quantity and quality of EOL solutions are vague and have exposed a high degree of uncertainty in CLSC [7]. Uncertainties can be found in situations where the manufacturer or supplier needs to make a decision concerning the supply chain without much information and is unable to predict what the outcome will be. Remanufacturing faces numerous uncertainties in the process due to limitations in material flow and time management [8][9][10].

Over the past years, the growing concern of researchers on CLSC optimisation and managing product return flow has resulted in the development of various mathematical models in order to attempt to solve problems occurring in the CLSC. Hence, it is empirical that the studies are extensively analysed in order to find potential areas to be explored. While there exist a review on uncertainties regarding quantitative models in the CLSC literature [11], an informative trend analysis on the uncertainty aspects, problem categorization and modelling techniques have yet to be found. To address the mentioned gap, the objective of this study is to structure and classify the existing research streams that focus on optimization problems of the remanufacturing sector, categorize the types of uncertainty considerations in modelling remanufacturing systems, as well as classify the modelling and solution techniques utilized by researchers from 2013 to 2021. As such, the main contribution of this study is to provide a comprehensive analysis on the research trends encompassing the problems classifications, uncertainty categories, modelling techniques and solution approaches of remanufacturing systems for the said years. All materials were selected within the past eight years to identify the latest trends of mathematical modelling problems and methods within the CLSC research that have been considered by researchers.

This paper is organised as follows: previous review papers are presented in Section 2. Material evaluation and selection process are evaluated in Section 3. In Section 4, a comprehensive analysis of the selected papers is elaborated. Finally, Section 5 comprises a gap analysis and future research topics, while Section 6 presents concluding remarks of the study.

II. PAST REVIEWS

Trends in supply chain research and practice can be identified by referring to published review papers. These papers are organised into categories and content analysis of research done in the past, current, and future, and each of them has its focus and interest. Authors often review selected papers based on their perspectives on matters such as classification, problem consideration, methodology and other similar topics. For example, Sasikumar et al. [12] review the literature of RSC inventory management issues for EOL product recovery. This research has caught the attention of other researchers since Akçcal et al. [13] categorised existing quantitative CLSC literature for inventory and production planners to encourage practical implementation of remanufacturing. The following year, Simangunsong et al. [14] identified the types of supply uncertainties in business and management databases by classifying uncertainties, approaches to mitigate the impact and methods for managing the uncertainties.

Regarding the RL process, Agrawal et al. [15] analysed 242 published reverse logistic articles on the specific methodology, process and gaps for future research. Meanwhile Govindan et al. [3] published a review paper that relate to CLSC/RL where 382 published papers were analysed that addressed modelling, problem classification, methodologies and ideas for future research. However, a slightly different perspective of the review was done by Ivanov et al. [16] when authors analysed different types of research that relate to ripple effects with different approaches; pro-active and pre-active. Also, in another published review paper, Ivanov et al. [17] underlined existing quantitative research concerning disruption and recovery. Cannella et al. [18] investigated the relationship between varying order policies, amplification of inventory for CLSC dynamics and a variation of logistics’ factors. Consequently, a review that considered inventory systems in reverse logistics was performed by reviewing the economic orderquantity/economic production quantity (EOQ/EPQ) and the joint economic lot size (JELS) models, which has been the central element in a review paper by Bazan et al. [19].
The interest in CLSC research did not see a decline. Govindan & Soleimani [20] reviewed 83 papers up to December 2014 relating to reverse logistics and CLSC from the Journal of Cleaner Production perspective. Another review paper by Govindan et al. [21] reported on the stochastic optimisation techniques for supply chain network design (SCND). In addition, the comparison of mitigating factors and causes of the bullwhip effect in CLSC has been rigorously discussed by Braz et al. [22].

In recent years, the reviews of CLSC still caught the attention of researchers since the latest review paper by Shekarian [23] investigated in-depth factors of game theory (GT) papers that influence CLSCs. Goltsos et al. [24] systematically reviewed articles particularly on dynamic CLSC systems regarding inventory and production control, forecasting and collection. A more recent review paper by Peng et al. [11] provided a great exposure of uncertainty factors, methods, and solutions for CLSC from a multidimensional perspective. Motivated by the past reviews, this review paper aims to highlight the research trends on CLSC mathematical modelling and techniques in solving problems regarding remanufacturing uncertainties from the years 2013 until 2021. To the best of our knowledge, a review with a particular focus on uncertainty trends in remanufacturing problems has not been fully adapted for the said years.

III. RESEARCH SCOPE AND METHODOLOGY

In this section, the adoption and some modification from the existing methodology of Govindan and Soleimani [20], Goltsos et al. [24] and Tranfield et al. [25] to conduct a systematic review of the existing literature in remanufacturing is presented, specifically based on evidence-informed managerial knowledge. Generally, the methodology in this study consists of a two-stage process, which is the identification of the main objective for review in the first stage and the selection of study based on assessment, data extraction and data synthesis that is elaborated under the second stage.

A. STAGE I- IDENTIFICATION OF THE MAIN OBJECTIVE AND RESEARCH QUESTIONS

This review paper is motivated by other CLSC review papers in order to analyse in-depth research in the CLSC field that relate to specific problems in remanufacturing and uncertainty consideration. This review attempts to answer the following research questions:

1) RQ1. Which problems mostly affect CLSC performance?
2) RQ2. Which uncertainties mostly affect CLSC models?

B. STAGE II- MATERIAL EVALUATION METHOD

This section discoursed in detail the material evaluation method, selection of study based on assessment, data extraction and data synthesis carried out in producing this review paper. In general, this review paper analyzed and classified the literature available on CLSC/RL with a focus on uncertainty consideration. The process of selecting potential review materials is shown in the flow chart in Fig. 2. The process was divided into sequences, as follows:

- For each publication site (e.g., Scopus, Elsevier, and IEEE), ‘closed-loop supply chain’ and ‘remanufacturing’ keywords were entered in the publication search engine. For example, Scopus site showed approximately 8542 articles in the general scope of CLSC/RSC and remanufacturing. In order to narrow down the number of articles, a more advanced search with specific keywords such as ‘uncertainty’ and ‘mathematical’ were entered in the advanced search engine and the search results showed that 171 articles were related to the search criteria. The advanced search engine in Scopus aid to specifically identify and match the requirement of the article.

- Various articles from different publishers (refer to Fig. 3) have been selected and further analysed in the following section. The chart shows that articles pertaining to mathematical modelling in remanufacturing have been published more in the following journals: Journal of Cleaner Production, International Journal of Production Economics and Applied Mathematical Modelling.

- The number of articles published varies for each year, as shown in Fig. 3. All articles were filtered based on the steps in Table 1 for the final selection of articles that were included in the review. The year range was set between 2013 until 2021. 2013 was selected as the starting year, as by observation of trends, the interest in the remanufacturing sector was seen to grow after the said year.

The actual result from the search engine showed 171 related articles from various publications. As illustrated in Fig. 4, the publication year of the selected papers shows a fluctuating trend. However, mathematical modelling techniques are becoming popular in solving problems regarding remanufacturing and CLSC. The trend of the overall published papers is seen to increase by 13% from 2016 until 2021. After deep screening for each article by going through the abstract and undergoing a criteria selection process, about 118 manuscripts (68%) were finalised and reviewed. Another 32% unselected articles were irrelevant to the selection requirement, for example, the supply chain system only considered FSC, uncertainties are unproven, the mathematical model was unsupported in the study and the research did not belong to the field of remanufacturing.

After completing the article selection process, all articles were classified into problem consideration and uncertainty categories, which are discussed in detail under section 4. This is then followed by a discussion, gap analysis and conclusions for this review paper.
TABLE I  
CRITERIA SELECTION FOR ARTICLES

| Step | Details |
|------|---------|
| 1    | RL, RSC or CLSC |
| 2    | The publication is from recent to the previous five years (2013-2021) |
| 3    | Uncertainties consideration by authors |
| 4    | A quantitative model is preferred |
| 5    | Problem identified in each article is related to production planning, network design, facilities location, channel coordination, pricing, supplier selection, distribution networking, and inventory management |

Keywords “Closed loop supply chain” and “Remanufacturing” were entered in the Scopus, Elsevier and IEEE search engine

Set period range for published articles from 2013 until 2020

In advanced search, specific keywords were entered (uncertainties, mathematical model, quantitative etc.)

Articles were short-listed based on criteria in table 2

Does the article satisfy all criteria listed in table 2

Yes

Finalized articles were selected and reviewed

No

FIGURE 2. Flowchart for material evaluation

FIGURE 3. Selected publications based on various journal sources

FIGURE 4. Percentages of mathematical modelling papers related to uncertainty in remanufacturing over the years 2013-2021
IV. COMPREHENSIVE ANALYSIS OF THE LITERATURE

In this section, the selected papers were identified and organised into different categories based on the problem and the methodological approach. For the first section, all selected articles were classified according to the problem considered. Next, the uncertainty aspect of each paper was acknowledged and elaborated.

A. PROBLEM CLASSIFICATION

There are various types of problems in RL and CLSC studies. Although the authors undertake research in different areas with special aims, this paper has classified 118 previous articles regarding CLSC and remanufacturing into seven different problem categories, namely network design, production planning, channel coordination, contract, inventory management, pricing and supplier selection. The problem classification summary can be referred to Table 2 as follows:

| References | Uncertainty type |
|------------|------------------|
|            | Problem          |
| Cardoso et al. [26] | Inventory |
| Ramezani et al. [27] | Return rate |
| Vahdani et al. [28] | Demand |
| Amin et al. [29] | Cost |
| Jindal et al. [30] | Quality |
| Hatefi et al. [31] | Environment |
| Niknejad et al. [32] | Planning |
| Gao et al. [33] | Production |
| Soleimani et al. [34] | Management |
| Zikopoulos et al. [35] | Channel coordination |
| Jindal et al. [36] | Network design |
| Zhalbchian et al. [37] | Management design |
| Keyvanshokhoob et al. [38] | Customer demand |
| Talaei et al. [39] | Management cost |
| Mohajeri et al. [40] | Management quality |
| Habibi et al. [41] | Management environment |
| Amin et al. [42] | Contract planning |
| Yu et al. [43] | Contract production |
| Soleimani et al. [44] | Contract management |
| Amin and Baki [45] | Contract compensation |
| Masoudipour et al. [46] | Contract price |
| Jeihoonian et al. [47] | Contract supplier |
| Cui et al. [48] | Contract customer |
| Zeballos et al. [49] | Contract strategy |
| Liao [50] | Contract technology |
| Wu et al. [51] | Contract innovation |
| Yu et al. [52] | Contract infrastructure |
| Fatollahi-Fard et al. [53] | Contract logistics |
| Polo et al. [54] | Contract operations |
| Zhen et al. [55] | Contract finance |
| Mardan et al. [56] | Contract management |
| Yu et al. [57] | Contract risk |
| Liao et al. [58] | Contract policy |
| Zhang et al. [59] | Contract regulation |
| Zeballos et al. [60] | Contract compliance |
| Ondemir et al. [61] | Contract enforcement |
| Khatami et al. [62] | Management planning |
| Ma et al. [63] | Management production |
| W. Chen et al. [64] | Management manufacture |
| Inderfurth et al. [65] | Management service |
| Paydar et al. [66] | Management project |
| Mohammed et al. [67] | Management operation |
| Zhou et al. [68] | Management finance |
| Tian et al. [69] | Management quality |
| Fang et al. [70] | Management environment |
| Xiao et al. [71] | Management risk |
| Mota et al. [72] | Management strategy |
| H. Liao et al. [73] | Management technology |
| Saxena et al. [74] | Management innovation |
| Kim et al. [75] | Management infrastructure |
| Jiao et al. [76] | Management logistics |
| Shi et al. [77] | Management operations |
| Ouaret et al. [78] | Management finance |
| Wang et al. [79] | Management quality |
| Liao et al. [80] | Management environment |
| Liao & Li [81] | Management risk |
| Liao et al. [82] | Management strategy |
| Liao, Li, et al [83] | Management technology |
| Liao et al. [84] | Management innovation |
| Liao et al. [85] | Management infrastructure |
| Heydari et al. [86] | Management logistics |
| Ahmadi & Amin [87] | Management operations |
| Georgiadi et al. [88] | Management finance |
| Xie et al. [89] | Management quality |
| Heydari & Ghasemi [90] | Management environment |
| Zhao et al. [91] | Management risk |
| Lieckens et al. [92] | Management strategy |
| Chari et al. [93] | Management technology |
| Ye et al. [94] | Management innovation |
| Alqahtani et al. [95] | Management infrastructure |
| He [96] | Management operations |
| B. Liao [97] | Management finance |
| Mahnaz et al. [98] | Management quality |
| As’ad et al. [99] | Management environment |
| Ruiz-Torres et al. [100] | Management risk |
| Liao et al. [101] | Management strategy |
| Singha et al. [102] | Management technology |
| Yang et al. [103] | Management innovation |
| Diabat et al. [104] | Management infrastructure |
| Zhou et al. [105] | Management operations |
| Giri et al. [106] | Management finance |
| Dutta et al. [107] | Management quality |
| Shekarian et al. [108] | Management environment |
| Oh et al. [109] | Management risk |
| Simić et al. [110] | Management strategy |
| Kilic et al. [111] | Management technology |
| Mohammad et al. [112] | Management innovation |
| Liu et al. [113] | Management infrastructure |
| Dominguez et al. [114] | Management operations |
| Ben-Daya et al. [115] | Management finance |
| Giri & Masanta [116] | Management quality |
| Kumar et al. [117] | Management environment |
| Gong & Chao [118] | Management risk |
| Shin et al. [119] | Management strategy |
| Ponte et al. [120] | Management technology |
| Das & Dutta [121] | Management innovation |
| Liao & Deng [122] | Management infrastructure |
| Özgür et al. [123] | Management operations |
| Mahmoudzadeh et al. [124] | Management finance |
| Xiong et al. [125] | Management quality |
| Li et al. [126] | Management environment |
to design the support network [12]. CLSC network design can
receive scholarly attention as a strategic issue of prime importance.

In conservative supply chains, network design draws more
attention. The non-linear model proposed by Masoudipour et
al. [45] [48], aside from that, a variety of remanufacturing
considerations [43] [52] [55] [56], balancing the trade-off
developing a multi-objective model with uncertainties
in network design, such as addressing the CLSC problem by
considering transportation costs. The financial risks due to the
economic uncertainty and unmet demand can be minimised in
the study by Polo et al. [54] while Cardoso et al. [26] identified
the supply chain structures needed to maximise the expected
net present value (ENPV).

In summary, network design is one of the significant
strategic aspects that would affect the CLSC’s reliability in the
long run, since strategic decisions of the RL or CLSC
development include the number of facilities in the network,
their location and the area to be served, and their capacities or
volume. CLSC or RL network designs were studied through
various modelling techniques for different business scenarios
and the concept of remanufacturing design networks were
developed for a wide range of products that provide solutions
to diverse strategic issues.

2) PRODUCTION PLANNING

Production planning problems, which consist of disruption
occurring during the production process, were vastly studied
in the recent literature. These studies covered an area of CLSC
and RL in which problems are linked with the rate of
production during the reverse cycle (remanufacturing, recycle,
repair and refurbishment). It is crucial that the production flow
be carefully planned and monitored, as once the flow has been
disrupted, the performance of the whole company may be
affected. Production planning strategies that have been widely
discussed were identified by referring to existing publications,
which include developing remanufacturing operation patterns
[64] [69] [61] [60] [62] [84], setting lower bound regulations for
the recycling rate [70] [78] [65], inventory recovery [68],
reverse logistics [66] [75], and reconditioning scheme of the
remanufacturing process [79]. Besides that, some authors also
state about the condition of optimal production strategies for
CLSC [85] and the optimal remanufacturing quantity [82]
when uncertainties strike in order to overcome problems in production planning.

The condition and preservation of the environment have been emphasised by several authors in their research pertaining to production planning problems. Jiao et al. [76] generated robust CLSC designs that reduce the impact of uncertainty and greenhouse gas (GHG) emissions. Meanwhile, Liao & Li [81] demonstrates a theoretical foundation for remanufacturers to develop optimal ordering methods under demand uncertainty situations with reduction of environmental cost without volume up production input. He also included sustainable elements in his other studies, such as optimal distribution of processing routes and systems of reduce, reuse and recycle (3R) for quality coefficient of engine return [80]. Liao, Li, et al. [83] also stated that the effectiveness of strategies that help to balance between economical and environmental benefits can be risen up to 50% if the quality of return is properly investigated.

Mohammed et al. [67] also considered the idea of a sustainable environment in their study when developing an ecological CLSC with multi-period and multi-products by considering carbon footprint. This was supported by Ma et al. [63], Xiao et al. [71], Saxenan et al. [74] and Liao et al. [73] where they take into account environmental elements in their research. Apart from that, authors also highlighted the decision support tool for the planning and design of sustainable supply chains for strategic decisions and tactical ones under uncertainties [77].

In a nutshell, production planning has been a vast area of research that attempts to integrate the planning of manufacturing and remanufacturing processes. Some studies explore RL/CLSC planning and try to focus on procedures for tactical decision-making. Hence, production planning is an essential factor for industries to move forward and establish the conditions by which companies can achieve their goals.

3) CHANNEL COORDINATION

Channel coordination issues in the CLSC has increasingly caught the attention of researchers as it can reduce the adverse effects of conflict and demand uncertainty and eventually improve the CLSC performance [143][144]. Capacity limitation problem can be overcome by revenue sharing contract as stated in the study which can create a fair situation for RSC [90]. In other studies, Heydari et al. [89] analyzed the remanufacturing capacity for a two-stage RSC. Channel coordination problems related to the capacity that encompasses early large scale capacity and low volume capacity expansions of CLSC have been eagerly discussed in the study by Georgiadis & Athanasiou [87]. Researchers have touched on several areas, like dual-channel [88] and marketing strategies in the remanufacturing supply chain, for both the remanufacturer and retailer [91].

4) CONTRACT

The CLSC contract regarding participation and coordination in the remanufacturing system is still vague and thus, attract the attention of researchers to explore this field. A warranty is a contractual obligation incurred in the connection between the purchaser of a product with a manufacturer (seller/vendor). In the rare event when a purchased item fails prematurely or is unable to perform its intended function, the purpose of a guarantee is to establish liability. These contracts specify the expected consumer quality; if the amount of expected performance is not achieved, the buyer will receive compensation [94]. There are different types of contract that has been made between buyer and vendor including the optimal shipping decision and raw material procurement [97] variation of supply risk-sharing contracts under pricing for remanufacturing production quality and recycling [95][96], free replacement warranty policy for product remanufacturing [92], warranty to minimize the cost of remanufacturing products [94]. The production of CLSC can also achieve maximum benefit when 3R systems procurement reaches optimal quality coefficient [99]. Apart from that, other links of the contract were established, such as connections between the supplier and manufacturer [98] that determines the capacity of a new component due to unmet demand, and contracts involving the collector and remanufacturer [93] that addresses the return item quality, where a quality subject price contract was used between a two-stage RSC.

5) INVENTORY MANAGEMENT

One of the critical research problems in CLSC and RL is inventory management. Many studies focused on this issue when dealing with the remanufacturing process. Inventory management encompasses matters such as stock reordering, order quantity optimization, remanufacturing stock, new batch production, base stock, return collection stock and inventory problems that occur at facility centers.

The CLSC is affected during the remanufacturing process from failure to identify production inventory when exposed to supply disruption [101][102][105], the effectiveness of capacity restrictions [113], and bullwhip effect on inventory adjustment [68][120]. Similarly, by identifying the time taken for components to go through the remanufacturing process, authors such as Lieckens et al. [100] and Oh & Behdad [108] claimed that this event is also related to the inventory problem that may disrupt the performance of CLSCs. Additionally, the decision needs to be made wisely to control both operations (manufacturing and remanufacturing) in stochastic economic lot-sizing problems [110].

The bullwhip effect is well known to be a tremendous impact on inventory management due to the unpredictability of orders or demand in the supply chain. The uncertainty in demand is magnified in upstream production and may create low performance and inefficiency throughout the supply chain. This impact can be countered by several strategies, such as effectiveness of capacity restrictions [113], exact product exchange policy [121], accurately estimated returns volume [119], bullwhip inventory adjustment [68], and centralizing the manufacturer production [120]. Although this phenomenon has been widely discussed by researchers in the forward supply chain context, the impact it has on CLSC can
be distinct due to the differences in entities, network configuration and operations in CLSC [22]. Despite these known challenges, studies on bullwhip effect in the CLSC setting has not received ample attention and should be explored more by researchers.

Inventory management in logistics also contributes to the problems in CLSCs. Some of the aspects in logistics that are related to inventory management include shipping policy [114], identify consignment stock policy [115], orders issued [119], scheduling problem of the capacitated product [112], inventory allocation of a single warehouse [103], and trade-in program and return service [107][118]. Besides that, capacities at facilities and their dedicated locations are categorized as an inventory problem in CLSCs. Capacities at facility centres related to unreliable facilities subject to unpredictable inventory allocation with full or partial failures of products are studied further by Mohammad et al. [111]. The capacitated periodic-review inventory system was studied by Gong & Chao [117] to find the optimal expected total discounted cost of manufacturing and remanufacturing policies. Furthermore, a stochastic inventory model on the optimization of a fuzzy cost function was deeply investigated by Liao & Deng [122] that applied a taxation policy on the optimal strategies. On the other hand, some authors developed a model that maximized profit by identifying inventory planning [109], analysed a recovery framework to find optimal buy-back offer at the retailer level [106] and comparing the profits gained between forward and CLSC [116].

Inventory management in CLSC/RL focuses on the effective utilisation of resources to satisfy the expected demand in an efficient manner. Inventory management also acts as variables for the operational decision of RL / CLSC, such as the allocation of inventory to individual orders, the date by which the order is to be filled out and other short-term decisions.

6) PRICING

Pricing plays an important competitive role in today’s globalized business environment and creates competition between firms to attract customers. Among the competing firms, a new business trend has been observed where they join forces together on specific issues to improve customer satisfaction [128]. Some specific issues regarding pricing decisions are related to demand of remanufactured products [126], cost of single-class used products [125], services strategy framework [132] and opinions of consumers/experts about factors that influence the purchasing of the remanufactured product [130]. In terms of pricing strategies, improvement of revenue can be achieved by the effectiveness of service time [134]. While, Deng et al. [135] the impact of irregular patterns of recycling price, remanufacturers revenue and resources benefits changes when a variation of demand coefficient ratio of reused products and its recycling price exist.

The pricing context in the business environment is to exploit the profit to the fullest and to find the optimal solution regarding cost minimization for item replenishment [123], [127] and remanufacturing flow [124]. The acquisition price, the quality of the collected used products, the shortage penalty, and the remanufacturing costs was proven affected by random yield accommodation in the pricing model by Gan et al. [131].

Apart from that, the sustainable environment aspect has been studied by authors such as investigating decisions under government subsidy and pricing [129], carbon emission trading price, consumers’ low-carbon awareness and carbon emission [133]. Hence, pricing is not only a tool to increase the profit in CLSC, but it may also contribute to environmental conservation.

Subsidy is an amount of monetary assistance offered by the government to encourage green initiatives for the industrial sector. As producing and managing green operations require additional costs compared to normal operations, it is seen as an effective method to promote sustainability among manufacturers. In the remanufacturing supply chain, for example, factors such as returned EOL product condition, demands extra process and maintenance costs to the manufacturer, which is a demotivating factor for business owners to pursue an interest in the remanufacturing sector. Additionally, these costs affect the pricing of remanufactured parts where it is difficult to offer cheap prices to the consumer given the extra costs incurred, when the price should be lower than original new parts [125]. Therefore, government subsidies is an important aspect to promote remanufacturing activities and more studies are needed to look deeper into this aspect.

7) SUPPLIER SELECTION

Decision-making regarding the sourcing of intermediate inputs from within or outside of the firm’s boundaries has been considered as one of the strategic decisions in supply chain management [140], where CLSCs are not an exception. The evaluation of suppliers selection is vital to improving the profits of the firms [136].

Supplier risk has become one of the essential areas of supply chain risk, such as identifying the priority of products to be provided by suppliers [138][140]. In addition, backup supplier issues have been discussed by Taylor et al. [137], whereby the buyer has to make up the shortage from the emergency backup supplier after the contract supplier undergoes uncertainties in production. Rezaei et al. [141] developed a model to maximize profit by considering other supply resources, such as backup suppliers, procurement from uncertain suppliers, and spot market. Giri & Bardhan [139] analyze a two-echelon supply chain consisting of a retailer and manufacturer with one product that faces various uncertainties. The model developed by Govindan et al. [142] for order allocation and circular supplier selection in a multi-product CLSC by considering shortages due to demand uncertainty, capacitated green routing problem and multi-depot consideration.
8) PROBLEM ANALYSIS PERSPECTIVE
This section will discuss on the analysis of problems that have been considered in this review. The problem frequency is graphically illustrated in Fig. 5. Network design is the most common problem addressed in CLSC/RL for the preceding eight years period, which recorded 30% out of the 118 papers selected. The network design problem becomes dominant in the literature due to the complexity in designing a strategic network, that includes location, quantity, capacity and technology type of the facilities, whereas the operational/tactical level involves determining the production and purchase quantities, distribution and inventory holding, as well as shipments between established facilities [12]. Hence, the fact that a network design issue spends massive sums of capital in new facilities over a prolonged period makes the network design an incredibly significant problem. The production planning problem recorded 22%, which is the second highest percentage of problems in CLSC research studies. Production planning is known to be complicated because the features of the system flow need to be taken into account, consisting of extra costs during production, complexities in assigning the capacities of production, the price, demand, quality and customers’ acceptance between new and remanufactured products. The manufacturers must consider the substitution of remanufacturing and production for environmental conservation purposes. Meanwhile, issues related to inventory management seem to be the third highest problem, which showed approximately 19%, while the pricing problem in CLSC documented about 11%. Furthermore, the lowest problem that attracted less attention from researchers was channel coordination, contract and supplier selection when indicating only 6% of interest.

The trends of problem consideration is illustrated in Fig.6. As can be shown the network design problem was least preferable in 2015. However, this trend showed an increment in the following year until it reached a peak in 2017. This is believed to occur since network design problems become more complex due to the requirements from critical activities of CLSCs such as quality of return items, multi-type recovery methods to be used and consideration of environmental aspects in the cycle [47]. Consequently, the trend shows a decreasing pattern for the following years. This is in contrast with the production planning problem which recorded the highest number in 2018 and lowest in 2013 and 2016. Nevertheless, problems related to inventory, supplier and pricing caught the interest of researchers in recent years. In contrast, research in channel coordination and contract problems showed a slowdown trend in recent years, followed by network design and production planning as these problems are still expanding in the CLSC research field. It can be seen that the listed authors have different interests in their studies and the least attractive problems such as contract, supplier and pricing should be explored more in future research, such that effects of any complications related to the remanufacturing system can be minimised.

![FIGURE 5. Trends of problem consideration over the past eight years](image)

B. UNCERTAINTY CLASSIFICATION
In addition to the problems classification, the selected papers were also analysed based on uncertainties that occurred in the remanufacturing system. Supply chain uncertainty can be defined as decision making situations in the supply chain in which the decision maker does not know definitely what to decide due to the lack of information [14]. Meanwhile, disruption can be defined as one of the elements of uncertainty and defined as an interruption in a supply chain process that is caused by external or internal sources occurring during unexpected events, including machine breakdowns, terrorism, war, political conflicts, transportation failures, labour dispute, and natural disasters [145][146][147]. By referring to Table 2 in section 4.1, the types of uncertainties were identified and classified based on existing review papers [4][14][21] such as inventory uncertainty, return rate uncertainty, demand uncertainty, cost uncertainty, quality uncertainty and environmental uncertainty. The demand and return rate uncertainties are the most significant factors considered in developing CLSC models. Table 2 also indicates that some articles have addressed multiple uncertainties. Further analysis
of uncertainties will be discussed in detail in the following subsections.

1) DEMAND UNCERTAINTIES
Demand comprises of many parties such as demand from retailers, manufacturers, customers and suppliers. If the used items are not well distributed, this may affect the remanufacturing process performance. In view of this, the demand for used products depends on the return rate from the collection centers and suppliers [87][137][138][139]. Aside from that, customer demand also plays an important role when remanufactured products enter the market [28][29][60][75][102].

Demand uncertainties can also occur when facilities are interrupted. Manufacturers need to have an official warehouse, and decide on plant sizing and facilities location so that problems related to demand can be handled wisely. This uncertainty has been highlighted in the study by Amin and Baki [45], Govindan et al. [142], Mardan et al. [56] and Hatefi et al. [36]. Demand uncertainty in the sustainable CLSC context has also been investigated by Mohammed et al.[67], Soleimani et al. [44], Mota et al. [72], Liao & Deng [122] and Gao et al. [32]. Their studies consider environmental issues in their research when dealing with random demand. Besides that, Liao & Li [81] have analysed environmental cost when dealing with order-related issues subject to demand uncertainty.

Uncertainties in demand might also affect the total overall profit of the firms. If the firms cannot fulfil the orders from customers, the firms will have lost sales and backorders. Hence, several authors have analysed optimal policies for remanufacturing systems with consideration of price [45][55][95][114][125][128][130], production strategies [85], inventory [109], [137][138][139], and networking [26].

2) RETURN YIELD UNCERTAINTIES
The rate of return of used products in reverse chains is often erratic because the exact amount of used product cannot be appropriately estimated. Product lifecycle depends on its quality and origin. EOL products need to be collected, and a large amount of inspection needs to be done. Some used products that can still be remanufactured while no longer functioning is also sent to waste [36][66][69][92][108][127][140]. Nevertheless, in well-developed countries that practice remanufacturing processes in their industries, there is often still a crisis in the return rate. Some companies even encourage their customers to exchange used products for some reward [49].

However, due to a lack of knowledge and awareness on the importance of used products among users, the return rate frequently fluctuates. Users usually do not know the value of EOL products. Often, these products are discarded in the waste disposal unit, which makes reverse cycles more complicated, as the separation process takes a longer time. In order to compensate these issues, manufacturers have also taken initiatives to improve the collection facilities of used items [31][41][47]. Financial incentives, for example, are commonly used to increase the quantity of product returns, but need to be offered in a cost-effective manner [95]. Stock policies [115] and recycle price [135] also can be revised so that uncertainty in return rate can be solved. Returned items will not only conserve the environment but also give potential profit to the manufacturers [84][93][127].

3) INVENTORY UNCERTAINTIES
Each company has its own lot sizing policy, and inventory capacity is one of the significant concerns that relate to the remanufacturing, recycling, and refurbishment process. The remanufactured item needs to be stored and sold based on the demand of customers; however, few customers prefer remanufactured products since they assume that the lifespan for the remanufactured product is shorter compared to the newly manufactured product [89][111]. A manufacturer dealing with remanufacturing processes needs to think wisely about the production of their goods. Inventory capacities can be larger, yet this will be more costly. Most companies like to reduce cost and increase their profit margin; therefore, interest has grown in inventory uncertainties with authors focusing on improvement of inventory management in companies [68][101].

4) COST UNCERTAINTIES
The typical main objectives of modelling and optimisation are to maximize profit or to minimize loss to the company. Cost uncertainties in CLSC/RL may refer to the cost of the remanufactured item in the market. By considering the cost of processing the used item, the company needs to identify a suitable market price. Thus the return cost is the most common uncertainty found in CLSC/RL. According to Yang et al. [102] and Talaei et al. [39], return cost depends on the return rate of the recycled items sold to the collector, while Soleimani & Govindan [33] consider the return cost as associated to the market price of the returned product. Apart from that, cost uncertainty has been considered in the quantity and types of plants and collection centres that should be open [63], a reasonable revenue sharing ratio in the CLSC network [88], channel leadership and governmental interventions [129].

5) QUALITY UNCERTAINTIES
Quality uncertainty that occurs in CLSC is mostly related to the condition of the returned core to the remanufacturers. The condition of the returned cores directly influences the processing flow of the remanufacturing system [80]. Besides, the quality uncertainty aspect of cores is one of the clear distinctions between CLSCs and FSC [87]. In EOL remanufacturing, cores will be sent through different processing flows according to their condition, hence, the quality uncertainty of returned EOL cores adds complexity to both practical management and theoretical analysis. While the quality of returned items varies substantially due to varying working conditions during the usage stage, this has greatly lowered process efficiency and added to management complexity [83]. As such, remanufacturers use different types
of methods to measure the quality of returned cores, such as quality coefficient [58] and failure percentage [87].

An example of quality uncertainty is the study on EOL engines conducted by Liao et al. [99], which stated that the best quality EOL engines can be remanufactured as whole machines, while engines with unmet conditions will proceed to the dismantling process into key components. Thus, quality uncertainty is a major concern in remanufacturing as it will have an impact on the CLSC process flow and in turn creates significant additional costs to the remanufacturer. Therefore, optimisation models are essential to adequately manage quality uncertainty and establish a cost-effective remanufacturing facility in this sector.

6) ENVIRONMENTAL UNCERTAINTIES

Environmental uncertainties studied in the CLSC literature mainly consider factors caused by unexpected natural phenomena. From the study by Yu & Solvang [52], they concluded that configuration flexibility in the decision model for reverse logistics network design affects the overall performance in terms of efficiency, market environment and plant planning. Ramezani et al. [38] present the suitability and consistency of the proposed approach for robust, closed-loop logistics network design under an uncertain environment. Many authors do consider environmental effects such as carbon emission [32][37][39][67][71][133] and GHG emission [52] in their study; however, only some authors consider environmental uncertainties in their study.

7) MULTI-UNCERTAINTIES CONSIDERATION

The combination of return rate uncertainties and demand uncertainties has gained interest among researchers in order to get the optimal efficiency of remanufacturing systems in the CLSC [7][28][32][38][62][67][76][100][107][116][117][123][124][126]. Other famous multi-uncertainties that have been considered were demand uncertainties and cost uncertainties [33][39][63][102][129], inventory uncertainties and return uncertainties [37][90], quality uncertainty and demand uncertainty [57][73][79][84][131], demand uncertainties and return uncertainties [40][42][48][53][86][105][110][113], demand and procurement uncertainties [82], inventory uncertainties and demand uncertainties [37][106] and return yield uncertainties and environment uncertainties [27][71].

Multi-uncertainties are becoming more popular as in reality, it is common for CLSC/RL systems to have more than one type of uncertainty considering the complexity of such systems, hence, the need to improve its overall efficiency and productivity.

8) ANALYSIS OF UNCERTAINTY TRENDS

Many problems that occurred in CLSC/RL have caused undesired performance results in terms of quality, quantity, budget and services. Researchers seek to deal with this situation and diminish the probability of disruption in the CLSC/RL cycle; however, solving problems regarding uncertainty that occur in CLSC/RL is a complex task and requires robust algorithms or methods. Based on Fig. 7, the distribution of uncertainties analyzed over the past eight years shows that multi-uncertainties are the most commonly studied, at 39%. This is mainly due to the problems that arise in CLSC/RL are usually not only caused by a single uncertainty, but by a combination of multiple uncertainties. From Fig. 7, demand and return rate uncertainties were the second and third most considered by researchers, which indicate 27% and 23% respectively. Quality uncertainty is still relatively low in the CLSC/RL field of study (5%); however, uncertainties in inventory, environment and cost were least attractive to the researchers in their studies.

Based on the trend of uncertainties which is graphically illustrated in Fig. 8, the pattern of multi-uncertainties shows an increment for four cumulative years, from 2015 until reaching a peak in 2018. However, multi-uncertainties show a sharp decline in 2019 and increase slowly in the recent years. Similarly, other uncertainties such as demand, inventory, environment and cost also show a decreasing pattern during
2019. In contrast, the pattern of demand uncertainty is the most popular in 2017 and 2019 since customer demand is one of the most important principles in the supply chain. It is necessary to understand the demand pattern in order to fulfil any changes in customer orders. Even though the estimation of customer demand forecast is not always accurate, fully satisfying the customer demand is of extreme value [45].

Despite a declining pattern shown by demand uncertainty for the previous three years, it is still found as the most popular uncertainty in the recent years (2019 and 2021). As demand for remanufacturing in CLSC increases around the world, many researchers believe that the remanufacturing process is one of the best ways to save the environment. Environmental uncertainty, on the other hand, shows a fluctuated pattern from 2015 until 2021, which we believe is due to the researchers who not only focus on environmental uncertainties but the combination of other uncertainties in order to contribute to a more impactful optimization model of the CLSC.

Undoubtedly, uncertainty is an attribute that cannot be avoided in supply chains, no matter how ideal the supply chain is designed to be. Moreover, the complexities that exist in a CLSC raise the chance of having increased levels of uncertainty, or multiple uncertainties simultaneously. Uncertain supply of spare parts, including long lead time and high product costs, are examples of uncertainty that remanufacturers face nowadays. Uncertainty complicates any existing problem to a certain level, which consequently causes additional costs to the supply chain partners. These extra costs may be incurred due to unforeseen labor time, process modification, or product losses resulting from inefficient and inadequate plans to face the uncertainty in CLSC.

From the modelling perspective, it is found that most problems that are modelled with integrated uncertainty has effects to the optimal solution by incurring more loss to the objective function. For instance, a profit maximisation problem would have a lower objective function value, whereas a cost minimisation problem would result in a higher objective function value to achieve the optimal solution. Modelling problems in ideal environments are already NP-hard, hence adding uncertainty rises the complexity further. Ultimately, this emphasizes the need for more in-depth studies that develop practical solutions, such as decision support systems to aid managers for efficient decision-making during critical times.

### C. MODEL DEVELOPMENT TECHNIQUES

Various types of modelling techniques were developed by researchers to analyse problems in RL/CLSC. This paper will use the term mathematical modelling to represent decision modelling. The mathematical modelling techniques can be divided into 19 categories, as shown in Table 3.

The bar chart in Fig. 9 illustrates the various methods considered by the listed authors when dealing with mathematical modelling in CLSC. It is found that stochastic models and MILP are preferable models in CLSC/RL when compared to other modelling types, which recorded precisely 25% and 12% respectively. The interesting point to be highlighted in the graph is the percentage recorded (11%) by other mathematical modelling methods. The term ‘others’ can be referred to the new deliberation of methods in developing mathematical models by researchers such as fuzzy Delphi method, linear physical programming, multi-agent system and Hessian matrix.

The EOQ models showed approximately 10% interest in modelling problems in inventory management. Similarly, the mathematical model such as MINLM was recorded at 1% higher compared to MIM and SG, which indicates 6%. Besides that, ILP, MINLM, FMILP, FMOM, MOMILP and MOMINLP showed approximately 3% interest in authors that utilised these modelling types, while 2% was recorded for MOILP, QPM and SD. The other modelling techniques that

| Mathematical Model | Publication |
|--------------------|-------------|
| Economic order quantity (EOQ) | [73], [81], [82], [101], [102], [106], [115], [122], [127] |
| Fuzzy EOQ (FEOQ) | [77], [107] |
| Fuzzy mixed-integer linear programming model (FMILP) | [7], [31], [35] |
| Fuzzy multi-objective model (FMOM) | [74], [123] |
| Integer linear programming model (ILPM) | [41], [92], [108] |
| Laplace transform (LT) | [68] |
| Mixed-integer linear programming (MILP) | [26], [27], [60], [66], [111], [29], [30], [36], [38], [39], [42], [43], [51] |
| Mixed-integer model (MIM) | [46], [48], [52], [55], [62], [75], [110] |
| Mixed-integer non-linear model (MINLM) | [50], [54], [97], [103], [112], [114], [116], [136] |
| Multi-objective integer linear programming (MOILP) | [28], [140] |
| Multi-objective mixed-integer linear programming (MOMILP) | [56], [72], [142] |
| Multi-objective mixed-integer non-linear programming (MOMINLP) | [37], [63] |
| Non-linear programming model (NLPM) | [69] |
| Quadratic programming model (QPM) | [100], [124], [134] |
| Robust optimisation model (ROM) | [76] |
| System dynamics (SD) | [87], [94] |
| Semi-infinite programming model (SIPM) | [109] |
| Stackelberg games model (SG) | [93], [95], [129], [131], [133], [137] |
| Stochastic model (SM) | [32], [33], [78], [84], [85], [89], [90], [96], [98], [99], [104], [105], [34], [113], [117], [118], [126], [128], [135], [141], [44], [53], [57], [58], [64], [65], [67] |
| Stochastic MILP model (SMILP) | [47] |
| Others | [40], [61], [70], [71], [79], [80], [83], [91], [119], [120], [125], [130], [132], [138], [139] |
were least preferred with a record of about 1% include FEOQ, LT, NLPM, ROM, SIPM and SMILP.

The trend for the three most preferable mathematical modelling techniques for eight years is graphically depicted in Fig. 10. Stochastic modelling is popular since it has been used recurrently for solving models with uncertainty, whereas MILP models are used for a range of simple, single product, incapacitated models to multi-product and more complex models or multi-objective models. Consequently, other new approaches for mathematical modelling is seen to rise, presumably due to researchers who are eager in find more efficient techniques in CLSC problem optimisation.

D. SOLUTION APPROACHES FOR THE MATHEMATICAL MODELS

Following the model development phase, a solution approach is required to solve the mathematical models. By referring to [3], solution approaches can be divided into various categories: analytical or exact, simulation, heuristic approaches, multi-criteria decision making (MCDM) and others. As this paper focuses on quantitative mathematical modelling, six basic categories were identified and listed in table 4.

The use of analytical software such as GAMS, CPLEX, LINGO and MOSEK was desirable since mixed-integer linear programming (MILP) was the highest modelling preference among the selected papers. CPLEX software is a popular optimisation software concerning its suitability for solving MILP problems. Heuristic methods and meta-heuristic algorithms were used for solving large-scale problems. Genetic algorithm (GA), differential evolution algorithm and an iterative algorithm are examples of meta-heuristic algorithms. Benders’ decomposition techniques were used for optimal stochastic mixed-integer modelling, while Sample Average Approximation techniques were selected for solving stochastic optimisation for an estimate. Simulation techniques were one of the methods that studied uncertainties in real situations. A multi-criteria approach, such as G-TOPSIS, was used to identify the order to provide the ideal solution. An analysis of solution approaches is illustrated in Fig. 11.

The general exact solution is the most preferable which recorded 41% from 118 papers that were reviewed, followed by simulation and software (27%), MCDM and other approaches (26%), heuristic and meta-heuristic (10%), SAA (4%) and lastly, and Benders’ decomposition (3%). In solving the problem, several approaches are usually adopted depending on the complexity of the problem, and the solution is not possible using precise approaches. By reviewing the results of Fig. 11, general solution approaches such as GAMS, MATLAB, LINGO and CPLEX are commonly used to solve mathematical models as they are common methods which are known for their simplicity and ease of access to these off-the-shelf software. It is suggested that other types of models besides MILP be more acknowledged so that variations in the modelling properties can be established to comprehensively grasp the benefits of different techniques. Authors should discuss the results and how they can be interpreted from the perspective of previous studies and the working hypotheses. The findings and their implications should be discussed in the broadest context possible.

### TABLE IV

| Solution Approach                  | Authors |
|-----------------------------------|---------|
| Benders’ Decomposition            | [27], [38], [62] |
| General Exact Solution            | [7], [26], [29]–[36], [41]–[43], [45], [46], [48], [49], [60], [63], [66], [67], [72], [74], [76], [79], [83], [92], [101], [106], [108], [109], [114], [116], [123], [124], [126], [131], [133], [134], [136], [139], [140] |
| Heuristic/Meta-heuristic MCDM and Other Approaches | [37], [44], [47], [50], [55], [56], [75], [100], [104], [127] |
| Sample Average Approximation Simulation and Software | [28], [52], [93]–[96], [98], [99], [102], [103], [110], [120], [58], [122], [132], [135], [138], [68], [73], [80], [82], [85], [87], [88] |
Besides, integrating uncertainty into the problem categories that were less studied in the past literature should be explored more in future research so that potentially related risks in CLSC/RL can be avoided. These categories include pricing, supplier, channel coordination and contract problems, especially in RL since there are limited studies on problems involving uncertainties consideration.

Additionally, only a few studies include environmental concerns in their research when establishing a modelling approach that involves uncertainties and not many researchers, however, are applying their interest towards carbon emissions, GHG effects, and energy usage. In future works, these environmental aspects should be more addressed within remanufacturing industries, as to further enhance green initiatives and preserve environmental sustainability for future generations.

Another research direction that is worthwhile to be explored is pertaining to the recent Covid-19 global pandemic that has shaken many industries and left huge losses to companies worldwide. It would be interesting to comprehensively investigate the impact of the Covid-19 pandemic on CLSCs as to obtain insights on future preparedness of similar crisis. Investigating the uncertainties associated with the pandemic would be very useful to gain more practitioner insights on resiliency in the remanufacturing sector.

VI. CONCLUSION

CLSC optimisation has been a major topic of interest for researchers to explore over the past few years. In prior research, various problems in CLSC have been studied, and scholars continuously aim to solve the underlying uncertainties in numerous ways. This review has investigated on the recent trends of optimisation problems with remanufacturing uncertainties in CLSC for the past eight years. In this perspective, a total of 118 past research articles were chosen, ordered, and audited to discover and analyse trends on problems classifications, uncertainty categories, and modelling techniques. Additionally, the review has identified potential research gaps where more research can be positioned and future extensions for optimisation research of remanufacturing systems with uncertainties.

The main contribution of this review is to aid researchers in identifying the overall trends in problem considerations, uncertainties, mathematical modelling techniques and solution approaches in the CLSC. From the analysis, it has been shown that network design was the most commonly studied problem, where a majority of studies focused on finding an optimal solution for this problem subject to uncertainties. Apart from that, multiple uncertainties has gained the most interest from researchers due to its close approximation and applicability to the real-world remanufacturing settings. As for mathematical techniques, stochastic modelling recorded the highest utilisation, while for solution approaches, the general exact solution scored the highest among other approaches. While identification of these trends are important to ensure future
remanufacturing research remain significant or relevant, research gaps have been acknowledged as well such that future work can fulfill the needs of less explored niche areas.

Our review has considered theoretical papers, particularly those utilising mathematical modelling approach in their studies, while excluded case studies on the topic. More practical insights on remanufacturing uncertainties can be established if it were considered. Nonetheless, the practical view of uncertainty on remanufacturing systems is manifested through managerial insights of the reviewed works. The study of optimisation models for uncertainty in remanufacturing is crucial to assist managers in decision-making when faced with uncertainty issues. This includes the supply and quality of returned products, process capacity of facilities, as well as demand for remanufactured products, which should be optimal for remanufacturing businesses to survive. With proper planning and use of technology advancement, remanufacturing businesses can enhance operational efficiency and remain profitable despite the many challenges that arise.

Several limitations exist in this review paper, which can be further improved for establishing future research reviews. Firstly, other mathematical approaches need to be deeply analysed considering the rising growth of new robust methods to tackle the problems faced in the CLSC sector. For example, incorporating other keywords such as “stochastic” can be considered for future reviews considering the current trend being one of the most popular modelling methods used by researchers. Secondly, a limited number of problem categories that are quantitative in nature were considered, whereby adding more problems pertaining to qualitative research, such as risk management in CLSC would be an interesting way forward. Furthermore, survey-based studies that could capture the human perspectives of a problem would be beneficial in future reviews, especially in remanufacturing management research.

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