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Lifecycle Cost Affordability and Performance-Based Contracting – A Managerial Decision Framework Based on Literature Review

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ABSTRACT

This manuscript reviews and synthesizes the product service system, lifecycle affordability, and performance-based contracting (PBC) literature across supply chain management, operations management, and logistics discipline. The study is based on 128 peer-reviewed articles published between 2005 and 2023 in journals related to the supply chain, logistics, and operations management field. The study proposes a framework for lifecycle affordability (LCA) and key aspects of performance-based strategy design and management, performance specification, and cost elements. This study is a robust literature review of lifecycle affordability and performance-based contracting. It proposes a framework to assist in business-to-business managerial decision-making to reduce lifecycle costs.

Keywords: *lifecycle affordability, operations management, performance-based contract, supply chain*

1. INTRODUCTION

Many industries are characterized by significant capital-intensive assets and longer than normal life spans. Likewise, these assets operate to their full capacity during a product's lifecycle (Sols *et al.*, 2007). Creating operational readiness at a cost reduction for the capital-intensive industries while improving customer value at no additional cost for the customer generates profit opportunities for these industries. Of these industries, transportation, healthcare, and defense have witnessed significant investment in identifying and implementing a more affordable product support system to address this challenge (Kratz & Diaz, 2012), often described as the practice ofaffordability. The Department of Defense (DoD, 2012) has defined affordability as the extent to which the lifecycle cost of a program is in line with its long run investment and plans.

Several constructs of affordability are emerging in the manufacturing industry as the service proportion of output and profits are increasing (Wang *et al.*, 2011). Increased service efforts both enhance the competitiveness of businesses and create a source of value.

Manufacturing industries are increasingly collecting product lifecycle data to provide after-sales service for the lifecycle of an asset. These data and services can be used to increase the industry's asset utilization (Baines *et al.*, 2007). Finally, product support business models establish an affordable lifecycle perspective of product support systems from acquisition to maintenance and operations (Kratz & Diaz, 2012).

In practice, there is a wide gap between what a buyer can afford in a current purchase and what is afforded throughout the lifecycle of the product. This gap can be defined through the acquisition, maintenance, and sustainability of the product's needs, i.e., its lifecycle. Like any planned program activity, this is addressed early in the lifecycle by understanding a customer's constraints, using available information when procuring products, and considering both lifecycle costs and product performance. If affordability is not prioritized, buyers may commit to higher costs throughout the product lifecycle that exceed their budgets (DoD, 2012). Therefore, it is essential to prioritize affordability when making decisions through each milestone decision stage of a lifecycle (LaCivita & Walls, 2011; Mowen,1988).

Operating and maintenance costs are another important element in lifecycle costs. Estimating operating and maintenance costs can minimize an asset's total lifecycle cost (LCC). Labor, direct materials, and establishment costs are all examples of operating costs.

Additionally, maintenance expenditures include regularly scheduled maintenance, unplanned maintenance, and refurbishment resources. The important factor is determining the best maintenance service level to reach the minimum total cost (Woodward, 1997).

LCC refers to the sum of all costs over the complete life of a product or service. LCC includes design, manufacturing, installation, operating, maintenance, and upgrade costs. The customer's goal for products with higher postproduction costs is to minimize the total cost of product ownership. The manufacturer is responsible for the costs contributing to the product's price, whereas support, maintenance, and operation are the customer's responsibility. Dependingon the product, the responsibilities transfer; in some cases, the customer and manufacturer share these responsibilities (Sandborn, 2013). **Table 1** shows what sustainment costs contain.

Table 1 Sustainment costs adapted by Sandborn (2013)

Sustainment Costs	
Operation and Support	**Post-Manufacturing Support**
Operation expenses	Training
Financing (cost of money)	Warranty
Insurance	Legal/liability
Cost of failure	Disposal
Qualification/certification	Financing (cost of money)
Maintenance (spare parts)	Qualification/certification
Training	Refresh/redesign
Retirement and disposal	

According to Sandborn (2013), all support, operation, and sustainment costs are classifiedas post-production costs. Sustain refers to extending the duration of the lifecycle. Maintenance more often refers to activity that corrects a problem, whereas sustainment manages system evolution. Cohen *et al.* (2006) noted that selling spare components and after-sale services in the United States embodied 8% of the annual domestic product. In other words, customers spend at least $1 trillion each year to sustain assets they already own. Volkswagen's sales of spare parts alone were 20.4 billion USD in 2019, and all after-market activities accounted for about 28% of total revenue (87 Billion USD) (Volkswagen, 2022; Warren & Gibson, 2021). A sustainment-dominated system refers to the cost of maintaining operations during the lifecycle of a system that exceeds the initial acquisition cost (Feng *et al.*, 2007). Sandborn, P., and Lucyshyn, W. (2019) define sustainment-dominated systems as activities taken to maintain the operation of an existing system, including continuing to manufacture. Products with high lifecycle operations and support (O&S) costs, such as the Marine Corps CH-53K heavy lift helicopter, have a planned sustainment phase of over 40 years, where its operations and support costs will be over $37.5B. The post-production cost for the CH-53K is six times higher than the original production costs (Classi *et al.*, 2021). Sustainment costs exceed 80% of the sustainment dominant system's total cost of ownership (Berkowitz *et al.*, 2005); (Degraeve *et al.*, 2000); (Patra *et al.*, 2019). Classi *et al.* (2021) used systems thinking to evaluate different scenarios when performing sustainment-dominant systems redesign planning. Managers could apply their approach, and it has the potential to reduce lifecycle costs and increase system performance while forming redesign strategies.

The construct of affordability is still emerging and, without structure, can broaden to a point of misconception. Affordability encompasses three perspectives: customer affordability, manufacturer profitability, and supplier sustainability (Bankole *et al.*, 2012). This article presents a systematic literature review of papers published in operations management, supply chain management, and engineering journals from 2005 to 2023 to propose a structured understanding of lifecycle affordability (LCA), its reciprocating constructs, and a proposed research direction. There is a discussion of how this study can be applicable to similar industries with high post-production costs.

LCA becomes the core of lifecycle costing. Through the use of a systematic literature review this paper will investigate the following research questions related to lifecycle affordability in logistics and supply chain research:

How has life cycle affordability been represented in supply chain research to date?

- What methodologies have been used in research on LCA?
- What are the constructs of LCA?
- What are the gaps in the literature on LCA?

This study is broken into two parts – methodology and literature review of supply chain topics- and addresses the evolution of research on lifecycle affordability by taking studies in the literature and integrating findings across disciplines and industries. The following section will discuss the methodology used for the literature review and then present the systematic review results and a set of constructs of LCA.

2. PART 1: METHODOLOGY

In a literature review study, it is important to recognize each step in selecting and reviewing the literature relevant to the research question. The following methodology identifies the underlying structure behind the selection criteria, which leads to identifying the keygaps in the literature and a direction for future research and theory development.

The reviewing process started by searching for the most relevant papers in the literature while limiting to a determined set of peer-reviewed journals from 2005 to 2023. Journals were selected from the *Financial Times* list of the top 45 journals used in financial times research, as well as journals that were within the scope of supply chain management (SCM), logistics, and operations management. LCA is a relatively unexplored area in the literature, and thus, a limited number of journals were considered to fall outside of the scope based on identified keywords used in the primary search journals.

2.1 Search Criteria

The first review of the journal set was to identify studies that specifically identified LCA. The search was directed to all fields, not limited to specific keywords or titles. This set of results was then narrowed to journals published between 2005 and 2023. The findings, as summarized in **Table 2**, show the search results and number of articles that specified LCA.

Table 2 List of journals publishing LCA construct research to date

Journal	Number of Publications	Percent (%)
California Management Review	1	1
Decision Sciences	1	1
Engineering Management Journal	1	1
EURO Journal on Transportation and Logistics	1	1
European Management Journal	4	3
The International Journal of Life Cycle Assessment	1	1
International Journal of Logistics Management	4	3
International Journal of Physical Distribution & Logistics Management	8	6
International Journal of Production Research	17	13
Journal of Business Logistics	6	5
Journal of Operations Management	8	6
Journal of Operations and Production Management	3	2
Journal of Quality in Maintenance Engineering	1	1
Journal of Supply Chain Management	8	6
Management Science	14	11
Manufacturing & Service Operations Management	1	1
Operations Research	1	1
Production & Operations Management	33	26
Strategic Management Journal	8	6
Transportation Journal	2	2
Operations Management Research	1	1
Operations and Supply Chain Management	3	2
IEEE Transactions on Engineering Management	1	1
Total	128	100

Table 2 illustrates a strong emphasis on problem solving and decision-making journals such as the *Journal of Production and Operations Management and Management Science*. This study excluded conference proceedings, book chapters, and Ph.D. dissertations, limiting the selection to only peer-reviewed journal articles and thus enhancing the quality and relevance of the articles by restricting the article search (Newbert, 2007; Wilding *et al.*, 2012).

The first review was followed by a second phase of keyword search based on mining of keywords from the previously identified LCA publications. These terms were affordability, lifecycle, lifecycle cost, lifecycle product, total cost of ownership, postproduction cost, refurbishment, remanufacturing, asset management, fleet management, sustained dominated systems, performance-based logistics, performance-based contracting, asset acquisition, overhaul, maintenance, reliability, supportability, preventive maintenance, obsolescence, and product service system. The keywords were in line with costs associated with a product's lifecycle. In particular, examples of industries with highly intensive capital were automobile, infrastructure, aerospace, defense, petrochemical, transportation, utility, telecom, and aftermarket support; therefore, fleet management was included.

The findings further revealed the importance of this literature review formulating a decision-making framework as a foundation for lifecycle affordability. The framework has many managerial and academic contributions in many industries, for-profitcompanies, and non-profit organizations. Finally, keywords were combined where the words were identified as synonyms (e.g., overhaul, maintenance, and operations). The basis for investigation among these sources was first to review the literature for lifecycle affordability and second to explore the characteristics of affordability within a product's lifecycle. The intention was to find the constructs for LCA and potentially describe the underlying criteria for making strategic, affordable decisions.

2.2 Article Screening Process

All articles were briefly reviewed, and duplicate articles were eliminated. The initial search yielded 434 articles. These articles were reviewed for relevance based on titles and keywords, which reduced the number of articles to 196. From this set, the abstract and, in some cases, the whole paper was investigated to determine relevance. This process yielded 128 articles (**Figure 1**).

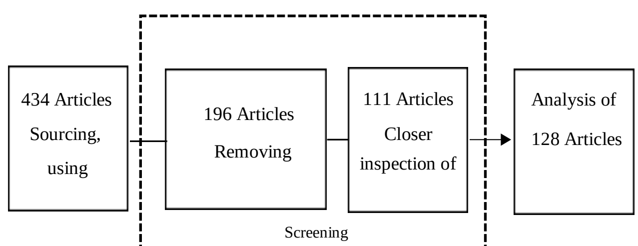

Figure 1 Overview of review process-sourcing, screening, and analyzing articles

Analysis

This stage mined and documented information from 128 sourcing articles. Information mined included identifying definitions, nature of the studies, methodologies, theories, methods of data collection, industries included in the article studies, and focus of thearticle study.

Table 3 Search terms

	Number of Articles	Percentage (%)
Remanufacturing	30	14.00
Fleet Management	22	10.14
Lifecycle Assessment	19	9.17
Product Service System	18	7.73
Product Lifecycle	14	6.76
Closed Loop Supply Chain	9	4.35
Lifecycle	8	3.86
Lifecycle cost	10	3.86
Refurbishment	7	3.38
Make-or-buy decisions	7	3.38
Residual value	2	1.00
Vehicle supply chain management	1	0.48
End of life	5	2.41
Maintenance	6	2.41
Obsolescence	5	2.41
Performance based logistics	14	6.76
Performance based contracting	18	6.76
Total cost of ownership	3	1.44
Performance measures	4	1.44
Capital investment	3	1.44
Trade-offs	2	1.00
Reliability	2	1.00

Tables were created to assess the overall research efforts indicated in the publications and the focus of the research efforts. This described what was already known and identified areas needing further evaluation to understand lifecycle affordability. **Table 3** lists thesearch terms with the number and percentage of articles, including the keyword. **Table 4** lists the theories and their frequency of use in the analyzed articles. Out of 128 articles, 86 articles applied theory in their research. **Figure 2** depicts the importance of quantitative analysis in supplychain management and logistics.

Mathematical models, especially non-linear programming, were used the most frequently in research studies. Remanufacturing, a construct of lifecycle affordability, was also a recurring concept. Searching keywords such as remanufacturing, reverse logistics, closed-loop supply chain and refurbishment sometimes identified the same or very similar journal articles. While remanufacturing and refurbishment are relatively new terms in the literature, fleet management has been the research focus of many scholars. In most articles, researchers used mathematical modeling to evaluate their studies. Of 128 journal articles, 48 studies provided modeling analytics in the research.

While there was a restriction for the publication date in the literature search, the review revealed that lifecycle affordability emerged in the early 2000s, first in the aerospace, defense, and capital industries. The significance of the growing interest in this research topic highlights the need for a thorough analysis of the expanding body of literature. The 128 selected articles were published in operations management, supply chain management, logistics, and operations research academic journals. *The Production and Operations Management Journal* dominated the number of publications in this area (30). The next journal with the highest number of publications was *Management Science* (14). The majority of the modeling analytical papers were published in *Management Science*. The *Strategic Management Journal*, *Journal of Operations Management*, *International Journal of Physical Distribution & Logistics Management*, *International Journal of Production Research*, *Journal of Supply Chain Management*, *Journal of Business Logistics*, and *International Journal of Logistics Management* had the highest numbers of publications in years 2005 to 2023.

Table 4 Theories in reviewed papers

Theory	Number of Articles	Percentage (%)
Transaction Cost Economics (TCE)	7	5
Resource Based View (RBV)	3	2
Systems Theory	4	3
Utility Theory	2	4
Lifecycle Theory	5	1
Renewal and Martingale Theory	1	5
Contract Theory	6	
Knowledge Based Theory (KBV)	2	2
Control Theory	2	2
Theory of Relationship Development	2	2
Complexity Theory	1	1
Theory of the Firm	3	2
Organizational Theory	3	2
Contingency Theory	1	1
Neoclassical Economic Theory	1	1
Reliability Theory	2	2
Principal Agent Theory	9	7
Inventory Theory	1	3
Performance Based Contracting	9	7
Performance Based logistics	4	5
Service Dominant Logic (SDL)	9	7
Graph Theory	1	1
Optimal Control theory	1	1
Real Options theory	2	2
Theory of Planned Behavior	2	2
Theory of Performance Frontier	1	1
Competitive Progression Theory	1	1
Game Theory	1	1
Total	86	
Not applicable (no theory used)	42	40

Reviewed papers were structured into strategies proposed and research methods. Sampling contained industries or countries for each specific research. The unit of analysis separated each study into individuals, firms, teams, networks, or sub-networks. Regarding extracting information from reviewed papers and organization, papers were classified according to Colicchia & Strozzi's study (2012) into research methodologies and then categorized into analytical and empirical research. Empirical research papers applied statistical sampling, case studies, an experimental design, or multi-methods. Analytical papers use conceptual, mathematical, or statistical methods (Hohenstein *et al*., 2015).

Research using an analytical approach was the favored methodology to explore LCA within the last ten years (48 out of 128). Case studies and experimental designs were used less extensively (27 out of 128). Considering LCA is a comparatively underexplored research discipline, this trend indicates the need for theory development in LCA.

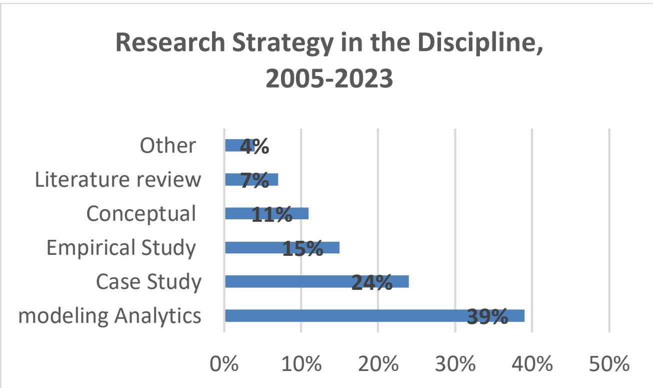

Figure 2 Methods used across the discipline

A maximum of 30% of the papers reviewed for this study used theory-based papers. Modeling analytics and empirical papers represented the dominant research methodology for lifecycle affordability constructs. Most studies used case studies to conduct their research, 29 studies out of 42 applied case studies. Of these 27 studies, 3 used experimental designs, 16 applied regression or statistical sampling, 18 studies used interviews as their primary methodology. Over 50% of the case studies were conducted with just one or two firms, with a more significant proportion being with a single firm. Only one case study used four industries, and another case used more than five industries to investigate maintenance and product service systems. Only a small number of the papers under review employed entirely deductive research methodologies to investigate a preconceived theory, underscoring the necessity for studies focused on theoretical exploration within this domain. Inductive research represented the majority of publications in case studies, empirical research, and modeling analytics. This research trend can better explain how real-world examples provide insights into understanding the complexity of real phenomena in the reviewed publications. Two studies utilized manager interviews as their data collection method (Bansal & McKnight, 2009; Randall *et al.*, 2010b). Four of the reviewed papers used surveys collected from organizations as their methodology for obtaining data. These papers indicated that more quantitative research done than qualitative research. Therefore, there is a need for rich and descriptive information. Twelve articles applied conceptual development as their methodology, and only two used grounded theory (Randall *et al.*, 2010b). Two papers dealt with system dynamics – Besiou *et al.* (2014) and Georgiadis *et al.* (2006). Rosenzweig and Easton (2010) was the only research paper reviewed that took a meta-analysis approach for their study on trade-offs in manufacturing. The empirical papers were mainly case studies of automobile or aerospace industries.

The reviewed papers contained a number of different industry sectors such as aerospace and defense, automobile, utilities, agriculture, manufacturing, new product development, service (buying rather than making), financial services, retail, government, and information systems. The diverse range of industries posed challenges in organizing the findings. Therefore, this study adopted Archibald's (2013) method of industry categorization. Nineteen specific interest groups (SICs) within a project management institute (PMI) related to different application areas. **Table 5** shows this categorization for the reviewed papers.

Table 5 List of industries and number of related publications

Industries	Number of Papers
1. Aerospace/defense	10
2. Automation systems	6
3. Automotive	7
4. Design/procurement/construction	6
5. Environmental management	2
6. Financial services (banking, investment)	1
7. Global communications technologies (management and movement of information)	3
8. Government	6
9. Hospitality (major events such as the Olympic Games)	5
10. Information systems (software)	4
11. International development (infrastructure, agriculture, education, health, etc.	3
12. Manufacturing	4
13. Marketing and sales	2
14. New product development	1
15. Pharmaceutical	0
16. Retail	1
17. Services and outsourcing (buying rather than making)	6
18. Utility industry (electric power, water, and gas)	2

3. PART 2: LITERATURE REVIEW OF SUPPLY CHAIN TOPICS

This portion of the paper delves into the 128 articles screened in Part 1 and analyzes specific topics relating to lifecycle affordability. It provides a robust literature review of lifecycle affordability across multiple disciplines and industries, creating both a systematic review of LCA information as well as a set of constructs for companies to utilize to reduce costs and improve customer service. The research questions are provided below.

1. What are the constructs of lifecycle cost affordability?
2. How does integrated supply chain continuity planning impact lifecycle affordability?
3. What are the performance measures for lifecycle affordability?

3.1 Supply Chain Considerations and Decisions

Product Service System

Pham *et al.* (2008) analyzed three sustainable product manufacturing realization levels (process, factory, and supply chain). They focused on meeting customer demands with efficient use of resources, distribution capacity, inventory, and labor. Looking carefully into a product's whole lifecycle (Ramani *et al.*, 2010), decision-making tools andinnovation are critical for a product's early decision process. Cost is a major manufacturing concern, Ramani, *et al.* (2010) considered logistical costs, such as transportation, distribution, and scheduling, as part of a product design.

Over time, businesses integrated products and services resulting in additional consumer loyalty (Olhager & Johansson, 2012; Mont, 2002), leading to a new business focus of product service. Product service system (PSS) shifted the management designing viewpoint from product-based to a service-based product (Kuo & Wang, 2012). Product-based service combines producers and lifecycle services to increase the product lifecycle, which makes it more affordable for the producer (Kuo & Wang, 2012) and eventually to the consumer.

When manufacturers and suppliers provide solutions, they offer results to satisfy their customers' needs rather than just being a vendors of goods. In product service systems, suppliers manage the product's lifecycle, and customers pay per unit of use or pay per unit of output. For durable products, the supplier can increase revenues by applying suitable strategies to extend the lifecycle and reutilization of the products (Xing *et al.*, 2013).

Goods and services can be combined into a solution package and offered to customers, whichrequires an integrated strategy to effectively define their relationship (Johansson & Olhager,2006; Yang *et al.*, 2009).

PSS focuses on satisfying customers' demands and increasing customer value (Geng & Chu, 2012). Such systems can also increase product use efficiency, lessen asset obsolescence and recycling, and extend product lifecycle. PSS is results-oriented. Specifically, the purchased utility is an outcome, not the use of the product over time (Chun Hsien *et al.*, 2014). PSS considers increasing product value and to support firms with product waste reduction (Chiu *et al.*, 2019). PSS is a network of players, that along with their supporting infrastructure to satisfy customers and lower the environmental impact of the product. Integration of products and services as a solution package needs product-service design (Xing *et al.*, 2013). Chun,*et al*. (2014) introduced the integrated product service system (IPSS), which uses the PSS contents and adds supply chain collaboration (SCC) to gain competitiveness. IPSS integrated the service concept. Li, A. Q. (2020) conducted a literature review on product-service systems. They investigated the theories used in PSS. They categorized theories into four clusters: systems theories, social and organizational theories, theories in resources and capabilities, and theories in psychology and behavior. Studies that used systems theory explain the co-creation of value in the PSS network (Ng *et al.*, 2009; Xing *et al.*, 2013; Batista *et al.*, 2017). The papers in this cluster also explain organizational changes (Turunen & Finne, 2014; Lee *et al.*, 2016) and business models (Tongur & Engwall, 2014; Lee *et al.*, 2015; Zhang *et al.*, 2017). Researchers have studied that PSS leads to higher revenues (Mont, 2002; Oliva & Kallenberg, 2003; Baines & W. Lightfoot, 2013). It also leads to sustainable customer relationships (Gebauer *et al.*, 2005); Sjödin *et al.*, 2016; Bustinza *et al.*, 2017)

Affordability

Affordability, simplistically identified as the gap between what a buyer can afford in a current purchase and what is afforded throughout the lifespan of the product, affects lifecycle costs and product performance and needs to be addressed as early as possible when procuring products (Mowen, 1988; Redman & Stratton, 2001). If affordability is not prioritized, the buyers may findthemselves committed to higher costs throughout the product lifecycle, exceeding their budgets (DoD, 2012; LaCivita & Wall, 2011).

Over time, the idea of affordability has developed into a characteristic that encompasses the consumer's need for a minimum performance quality while simultaneously being responsive to performance, buyer's price, and availability needs. A more modern definition of affordability has aholistic view. It refers to a system that is able to operate at the designed level and maintains and supports the assigned cycle budget (LaCivita & Wall, 2011). System affordability refers to the balance between the performance of a system, total ownership costs, and schedule restraints over the entire system's lifespan when the mission needs are aligned with strategic investment and organizational needs (Schaffner *et al.*, 2013).

System affordability is crucial when considering the lifecycle of a product, including resource planning, intelligence, acquisition communities, and component programming. The DoD (2012) emphasizes affordability throughout the lifecycle cost of a program due to long-run investment and plans. The DoD (2012) utilizes cost analysts when planning a program to ensure affordability based on data and rationality, and is indispensable to achieve high performance (Mardiasmo *et al.*, 2008). Redman and Stratton (2001) consider affordability to be an important metric in system engineering and break affordability down into three major sections: program phase costs, LCC, and total cost of ownership (TCO).

Along with affordability, buyers and suppliers must improve their operational efficiencies and grow their businesses. As the costs of technologies decrease, businesses can leverage these advancements to access affordable energy, products, and financial services more readily, thereby enhancing their productivity and efficiency. Affordability entails the capacity to provide products at lower prices to consumers. In essence, innovations prioritizing accessibility and affordability contribute to the survival of businesses and ensure that consumers can access goods and services at an affordable rate. Accessibility refers to the ability of the customers or buyers to receive services supporting their operations (Escamilla *et al.*, 2021).

Cost Elements

Several cost factors impact lifecycle affordability. LCC and TCO were useful decision approaches in automotive acquisition since the total cost of operating a vehicle went beyond its acquisition costs. Indirect and direct costs were carefully considered during the lifecycle stages, including acquisition, deployment, operations, maintenance, deposition, and salvage of the capital-intensive asset (Johnson *et al.,* 2011). According to Fawcett and Waller (2014), the optimal decision in acquisition planning was to maximize the net profits of the carriers over their lifecycle. Net profit was the difference between gross revenue earned by the equipment and all the expenses incurred when purchasing and maintaining the product over its lifetime. Depreciation of high capital-intensive assets was inevitable. Therefore, a purchasing and maintenance budg*et al*located for equipment was necessary. Factors affecting profit were initial purchasing costs and maintenance costs. Equipment with higher initial costs tended to have higher annual maintenance costs. According to sensitivity analysis by Bhadury *et al.* (2006), initial equipment cost was a key index of equipment annual costs. There was also a strong correlation between the profit to cost ratio and initial equipment costs. Bhadury *et al.* (2006) determined that the optimal policy for replacement was not affected by the annual maintenance costs. They also found that annual profits decreased when annual maintenance costs increased. Further, they took an LCC and TCO approachto analysis for decision-makers.

Table 6 History of LCC

Author(s)	Concept
(Cavinato, 1992)	Total cost
(Ellram, 1993)	Total cost of ownership; suggested pre-transaction cost component structure, pre-transaction cost components, transaction cost components, and post transaction
(Shields & Young, 1991)	Product lifecycle costs
(Jackson & Ostrom, 1980)	Lifecycle costing
(Ellram, 1995)	TCO depends on activity based costing
(Tyndall, 1988)	Measuring TCO based on logistics cost management in distribution chain
(Bennet & Timbrell, 2000)	Measuring and reducing TCO based on activity-based costing
(Ersten, 1998)	Market exists for TCO soft wares
(Ellram & Perrott Siferd, 1993)	Categorizing TCO into quality management, delivery, service, communications, and price

Acquisition planning was an important tool for decision-makers to use when determining consistent financial metrics for budgeting, cash flow analysis, and asset management. Based on Bhadury *et al.'s* (2006) analysis, the acquisition planning strategy needed to be changed for asset intensive capital every five years. Companies need to adopt profit cost analysis to better maximize the return on their investment. Information about the salvage value of different equipment was highly correlated to initial equipment costs, maintenance costs, and annual revenues. Finally, the acquisition model suggested insight into purchase decision-making for the automotive industry.

Total cost of ownership was an integrating concept presented by Ellram and Perrott Siferd (1993). They defined TCO as the cost of a series of activities associated with the purchase of goodsand services. Avery *et al.* (1999) argued that companies used to focus on direct costs, mainly purchasing prices, assuming that indirect prices would fall as direct prices went down. However, Avery *et al.* (1999) posited that companies realized that direct and indirect costs would not be reduced over time. Managers were responsible for reducing the indirect costs.

Table 6 shows the brief history of total cost, total cost ownership, and other related concepts throughout the 128 analyzed articles.

Industry Applications of Lifecycle Affordability

Characteristics of lifecycle affordability are investigated throughout the existing literature. After that, based on the criteria found specific for affordability in the context of the study extending the lifecycle of products, a decision-making framework and a set of propositions areproposed, establishing a foundation for further empirical investigation. **Table 7** provides a collection of studies in the literature that mentioned reducing lifecycle costs and making more affordable products or assets.

3.2 Integrated Supply Chain Continuity Planning

Integrated supply chain continuity planning (IBCP) is introduced in this study as one of the decisions for the lifecycle affordability framework provided later in this study. IBCP identifies potential problems in advance while capital equipment needs are monitored to ensure an organization can maintain a competitive advantage during unanticipated events (Elliott *et al.,* 1999). Owning inherent uncertainty involves uncertainty of a product's performance and the need for spare parts during the product's lifecycle. When asset specificity and outcome uncertainty are both high, short-term contracts have less interest. Since capital acquisition decisions are long-term decisions that might be transferred from one manager to the next, supply chain continuity planning can help managers make smooth decisions as they transition, ensuring continuous support throughout the organization's supply chain (Jones & Zsidisin, 2008).

Performance Based Logistics

Performance-based logistics (PBL) is a post-production service strategy with an integrated supply chain management network system that includes research engineering, operations, maintenance, support, logistics, purchasing, and supply chain activities and decisions (Randall *et al.,* 2011). The objectives of PBL strategies are to improve performance and decrease the lifecycle costs of the system, with lifecycle costs being the most important and requiring strategic thought (Yoho *et al.,* 2013).

In traditional postproduction support, the system operator manages the supply chain, including maintenance and postproduction logistics support. However, the latter is different from the core competency of the operator (Randall *et al.,* 2011). The original equipment manufacturer (OEM) can decrease the lifecycle cost of the system when the system operator does not have enough funding to reduce the system lifecycle costs while increasing reliability or redesigning the system (Randall & Farris, 2009). PBL propels a governance structure that acts as a system integrator and encourages the supplier to invest in innovation and knowledge to avoid future costs (Randall *et al.*, 2011). Tadelis (2002) looked into innovation with contracts and created a make-or-buy decision model in which relationships are governed by costs of contract design for a relationship in a market-based environment. According to Bajari and Tadelis (2001) and Tadelis (2002), the timing of the contract (endogeneity) for contractual incompleteness affects the contract design and system performance since it is too costly for firms to specify all contingencies.

One fundamental difference between traditional postproduction support services and PBL isthe delivery of service. PBL strives to reduce long-term costs while improving performance by eliminating waste. It is centered on innovation and product improvements that reduce lifecycle costs with waste elimination through improvement in technology and processes (Randall *et al.*, 2012). Thus, a PBL contract supplier's initial costs may increase with investment in innovation andimprovements.

In terms of performance strategy, there are key differences between outsourcing and integration. Fallah-Fini *et al.* (2012) compared traditional maintenance practices with performance-based maintenance strategies from 2002 to 2007 to compare two contracting strategies forinterstate highway maintenance. With outsourcing, there was a high level of performance in the product's initial lifecycle since the terms of the contract needed to be satisfied. Novak and Stern (2008) argued that internal projects had relatively higher performance over the entire length of the lifecycle of the product, allowing adaptation as the firm faced potential contingencies.

Another difference between outsourcing and integration was that the knowledge developed and accumulated in outsourcing was encouraged to be shared with other firms in the network, while integration encouraged the knowledge developed to be applied in firm-specific applications (Nickerson & Zenger, 2004; Novak & Stern, 2008). According to Novak and Stern (2008), suppliers offering performance contracts demonstrated two benefits during the early years of theproduct lifecycle: (a) access to technology and innovation, as well as the ability to enforce the performance contract, and (b) outsourcing, was beneficial to short-term performance measures.

Internal development teams tend to be regulated by wage contracts and authority relationships, which affect how the performance contract is enforced between the supplier and the firm (Novak & Stern, 2008). Also, there was a trade-off between risk and reward in performance-based contracts when considering sparing versus redesign (Randall *et al.*, 2014). According to Randall *et al.* (2015), interfirm teams require knowledge of cost and performance details in the contract as well as all the costs in the supply chain network. They could reduce total lifecycle costs by integrating knowledge and innovation.

During the later years of the product's lifecycle, the lack of authority relationship among internal teams can affect quality of performance. Novak and Stern (2008) elaborated that innovation was critical during the initial phase of the product's lifecycle, and in later years, postproduction knowledge was required for performance improvement. They noted that suppliers with incentives to share information with the downstream supply chain might hurt the suppliers by losing the advantage in contracting.

Table 7 Lifecycle cost reduction and affordability

Authors	Application Context	Emphasis
(Kim *et al.*, 2007)		Cost-sharing incentive and a performance incentive
(Jones & Zsidisin, 2008)	Aircraft	Through renewing, upgrading, and overhaul
(Sols *et al.*, 2007)	Complex system	Component refurbishment
(Bernstein & Kök, 2009)		Target-priced contracting
(Priya Datta & Roy, 2011)		Servitization
(Randall *et al.*, 2010b)	Logistics system	Logistics managers
(Randall *et al.*, 2011)	Logistics system	Industry, government, and academics
(Randall *et al.*, 2012)		Cost avoidance potential
(Yoho *et al.*, 2013)	Aircraft	Risk-sharing
(Christopher & Ryals, 2014)	Engine life	Performance-based contract
(S. Randall *et al.*, 2014)	Government and industry	Incentive for upfront investment
(Chun Hsien *et al.*, 2014)	Software industry	PSS
(Randall *et al.*, 2015)	Large-scale complex systems such as those found in aerospace and defense, utilities, healthcare, and social sciences	Aligning innovative activities and investments on common goals
(Selviaridis & Norrman, 2014)	Service delivery	Managing risk through contractual relationships
(Selviaridis & Norrman, 2015)	Logistics providers	Designing, adopting and managing PBC
(Batista *et al.*, 2017)	Manufacturers in defense industry	Fundamental features of out-come based service systems
(Patra *et al.*, 2019)	Construction equipment industry	Increasing operational availability
(Hur *et al.*, 2018)	Aircraft-spare parts	End of life inventory control of aircraft spare parts under PBC
(Escamilla *et al.*, 2021)	Nano store supply chains	Improving Agility, Adaptability, Alignment, Accessibility, and Affordability

Performance-based strategies have been used across multiple industries with great success in reducing lifecycle costs. **Table 8** shows the studies that explained lifecycle cost reduction through performance-based strategy.

Refurbishment and Remanufacturing

Refurbishment and remanufacturing are also components of lifecycle affordability in the industry. Remanufacturing refers to rebuilding the product or components of a product to increase the value added to the product (Rose *et al.*, 2000).

Table 8 Definitions of reducing lifecycle costs throughperformance-based strategy used in literature

Authors	Definitions	Application Context	Emphasis
(Randall *et al.*, 2010)	PBL shifts responsibility for system performance from end-user to the upstream supplier network. The supplier network is compensated based on the ability to deliver a performance- based outcome, instead of being paid to overhaul parts or provide replacement components	Defense	Risk Transfer to supplier network
(Priya Datta & Roy, 2011)	BLs are an example of result-oriented industrial PSS. All associated parties need to understand the process, competencies and assets required to deliver the customer's required performance level. Through incentives or penalties, involved parties need to improve performance over contract period.	Defense	
(Randall *et al.*, 2011)	PBL is a post-production service strategy that is highly dependent on the supply chain supporting its logistics ecosystem. Complex systems being supported through a PBL strategy rely on activities and decisions that span across a broad array of functional areas including research and development, engineering, operations, maintenance, support, logistics, purchasing, and supply chain.	Defense	Aligning incentives among customer and supplier
(Guajardo, *et al.*, 2012)	Supplier is paid based on the realized outcome of customer value. For example, an airline customer pays an engine service provider in proportion to the number of aircraft flying hours, which is affected by engine uptime (i.e., the number of hours the engine was available for use), and which determines the value derived by the customer.	Aircraft, engines, semiconductor	Aligning incentives among customer and supplier
(Christopher & Ryals, 2014)	Service provider is rewarded for performance outcome rather than for a provision of a specific activity. For example, rather than charging for space occupied in a warehouse the service provider must be rewarded on the achievement of improved levels of on-time, in-full deliveries.		Payment linked to achievement of specified outcomes, outputs, or quality.
(MacCormack & Mishra, 2015)	Defined performance-based contracts as including contracts where partner payments were contingent upon the partner's overall performance of the final product (e.g. in terms of revenue	R&D projects	Partner integration and partner performance
(Patra *et al.*, 2019)	Studied the optimal level of availability of products that maximizes a supplier's net profit. They show that when a supplier's per-unit revenue increases, the operational availability increases. The supplier's net profit decreases when operations and maintenance costs per unit increase.	Construction Industry	Increasing perational availability
(Classi *et al.*, 2021)	To decrease lifecycle costs, enhance performance, and address obsolescence challenges by expanding the planning model's scope and incorporating a broader range of decision parameters in the formulation of redesign strategies	Large-scale complex sustainment-dominated systems	Obsolescence mitigation

By investing in more costly refurbishing processes, the quality of refurbished products might be improved; however, the quality of refurbished products is difficult to measure since the quality also depends on consumer perception. However, remanufacturing provides a promising opportunity for environmental, social, and economic sustainability (Giuntini, R., Gaudette, K., 2003). According to Geyer *et al.* (2007), when the capacity of manufacturing satisfies demand, it is optimal to either not refurbish any returns or refurbish a large proportion of returns. If a firm makes money on remanufactured products and associated services, the firm may want to invest in refurbishing its products. However, the supply of remanufactured products is only a fraction of new product sales. To increase the supply of remanufactured products, a firm can lower the price of new high-end products and increase the sales quantity of itsnew high end. Eventually, it can increase the supply of remanufactured high-end products (Ovchinnikov *et al.*, 2014).

The price of remanufactured products is lower than that of a new products, and remanufactured products cost less than new products (Webster & Mitra, 2007). Companies are motivated to remanufacture products because of economic considerations (Ginsberg, 2001; Toffel, 2003). Remanufacturing in process industries has received little research attention, and thus, there needs to be more theoretical support (French & LaForge, 2006). Webster and Mitra (2007) studied the return rate on costs and future sales when companies remanufactured products.

In many industries, manufacturers assist their suppliers in planning and making cost reductions by providing free consulting services. Some automobile companies have started long term relationships with suppliers (Bernstein & Kök, 2009). Total supply chain profit is lower under centralized investment decisions. At the end of usage of the products, the parts, goods, or products are collected and inspected for probable reuse. Products or components with viable original activity can be disassembled, overhauled, and used in replacement operations (Thierry *et al.*, 1995). Product demand can be satisfied with manufactured or remanufactured products. Copies,printer toner cartridges, single use cameras, and engine changes are some of the industrial examples of products that are frequently remanufactured. Industries adopt this strategy when there is pressure to reduce the flow of waste and transport obsolete products to landfills (Biehl 2007 *et al.*). Most importantly, this strategy satisfies the demand for less costly remanufactured products. Due to lifecycle patterns, there is a need for dynamic change of demand and returns (Georgiadis *et al.*, 2006).

Scientific literature has applied optimal control methodologies to compute capacity expansion. Guide and Van Wassenhove (2009) focused on profitable value recovery from returned products by looking over the literature. Agrawal *et al.* (2015) found that just offering remanufactured products reduced the perceived value of new products by up to 8%. They used behavioral experiments to study the impact of remanufactured products along with the identity of the remanufacturer on the perceived value of an OEM’s new products. In addition, they concluded that OEM-remanufactured products may reduce the OEM’s profit from high quality products such as Apple products. They also proposed that an OEM may benefit from the presence of a third-party remanufacturer because it would emphasize the difference between new and remanufactured products. Eventually, the quality perception of new products will be enforced.

System dynamics introduced by Forrester (1999) provided an easy and flexible model and simulation framework for long-lasting decision-making in dynamic systems. System dynamics was suitable in closed-loop diagrams that describing major feedback loops (Georgiadis *et al.*, 2006). Georgiadis *et al.* (2006) presented dynamic capacity planning developed through system dynamics to study how lifecycles and return patterns impacted remanufacturing capacities. They also investigated the long-term profitability of remanufacturing within reverse supply chains.

Copani and Behnam (2020) proposed a model for remanufacturing with upgraded PSS. They proposed four different types of remanufacturing. The first classification is Non-Systemic Remanufacturing, which refers to traditional suppliers providing remanufactured parts. Customers buy remanufactured products on demand at a reduced cost, and suppliers only offer services related to them; an example is Martela, a Finnish firm that provides furniture and interior solutions (Copani & Behnam, 2020).

The second classification is performance driven remanufacturing and upgrading PSS. Within this classification, companies provide services focused on performance enhancement or remanufacturing. Non-systematic performance-based upgrading refers to customers receive new products or components to facilitate performance improvements an example is Toshiba medical systems (Copani & Behnam, 2020).

Companies in the third classification incorporate integrated product remanufacturing with upgraded PSS; manufacturers adopt remanufacturing with upgrading to present products within the market. Customers in this classification gain access to enhanced features provided by products that undergo upgrades during the remanufacturing process. An example is Rolls Royce facilitating the timely replacement of aircraft engines during maintenance by partnering with authorized centers for inspection and disassembly (Copani & Behnam, 2020).

The fourth classification offers guaranteed performance for products under long-term service contracts. Under these contracts, customers receive periodic upgrades where service suppliers own the products and customers operate the products. Since suppliers own these products, they manage and plan the remanufacturing process and handle the reverse logistics phase (Copani & Behnam, 2020).

These four different remanufacturing classifications are viable strategies for creating sustainable advanced product-service systems. The organization’s capabilities for remanufacturing and upgrading products can pave the way for providing performance-based services, potentially revolutionizing customer consumption behavior.

3.3 Performance Measures

When looking at lifecycle affordability, performance measures are key components. Performance is described both in terms of service outputs and outcomes (Selviaridis & Norrman, 2014), with outputs referring to the service functionality and level of performance (e.g., machine availability percent) and outcomes referring to customer value derived from a given service (Hallikas *et al.*, 2014; Selviaridis *et al.*, 2013). Product reliability is one of the main financial performance drivers in after-sales product support, including maintenance, repair, and overhaul (MRO) operations. Bakshi *et al.* (2015) summarized resource-based contracts (RBC) as having suppliers being compensated proportionally to the number of resources used for spare parts. On theother hand, in PBL, the outcome was judged by performance, with the supplier being rewarded or penalized by the performance delivery (Kim *et al*., 2007; Randall *et al.*, 2011). PBL aligned incentives between buyer and supplier, resulting in more significant product usage while lowering the total lifecycle cost (Bakshi *et al*., 2015; Randall *et al*., 2011). According to the U.S. Government Accountability Office (2004), buyers preferred RBC over PBL since there was no baseline data publicly available on product reliability. When product reliability was unambiguous to buyers under PBL, they considered RBC as the better offer since it had better value (Bakshi *et al*., 2015).

Topics related to system use and system effectiveness are considered as performance. Supportability is one of the performance measures of the logistics system (Sols *et al.*, 2007). Manycustomers have capital intensive systems. For example, the Spanish railway state company has a 14-year-old performance-based contract with a train manufacturer. Under the contract, the railwaycompany rewards the operator based on operational performance measures such as availability and reliability. The contract is based on the knowledge and experience of the operator, who is motivated based on penalties and rewards listed in the contract. The operator can be more innovative under PBL contracts since rewards and penalties are based on results, not efforts deployed. Kim *et al.* (2010) found that PBL is more successful in incentivizing suppliers to invest in reliability improvements than RBC. However, both PBL and RBC tend to increase the size of inventory. PBLresults in a win-win scenario where there is less need for inventory investment, and products are more reliable.

Another major trend evident in the literature was servitization. Vandermerwe and Rada (1988) discussed servitization, where innovation of an organization's processes and capabilities created mutual value by selling product-service systems rather than selling products. Servitization occurred when manufacturing moved away from transactional sales to relational marketing where long-term contracts were based on the relationship between supplier and customer instead ofsimply selling products (Neely, 2008).

Performance is evaluated both the end-user and the supplier levels. At the user's level, terms of impact on beneficiaries are evaluated, and at the supplier level, technical and financial performances are considered (de la Garza & Arcella, 2013; Selviaridis & Wynstra, 2015). Measurement, monitoring, and reporting incur high administrative costs. Performance metric design is contingent on performance measurability (Heinrich & Choi, 2007; Wisten, 2011). Customer's requirements are reflected in performance indicators and by developing service systems to meet users' needs (Falisse *et al*., 2012; Molenaar & Navarro, 2011). Performance reflects supplier learning as a reaction to rewards (Ozbek & de la Garza, 2011). Matthew *et al.* (2011) and Persona *et al.* (2007) focus on forecasting, maintenance outsourcing,and e-maintenance, which incorporate tools and data into planning to meet demand.

Performance measure literature is diverse, and this has caused authors to focus on different aspects of performance measurement systems (Neely *et al.*, 2005). (Alhaddi, 2023) contributes to performance measurement literature by addressing three key aspects: pointing out the insufficient exploration of effectiveness, which complements the well-studied efficiency; identifying 'practical implementation' as the current research stage; and emphasizing the importance of adopting innovative theoretical perspectives. Kuo and Wang (2012) developed a performance utility model to explain what factors influence the service satisfaction from the customer's perspective. Factors such as reliability, responsiveness, and customer perceptions can significantly impact the performance utility model. Improving performance utility is most effective through cost improvement. Total cost is improved by improving maintenance cost throughout the entire network chain.

Lifecycle affordability is easily seen in financial statements. Hofmann and Kotzab (2010) proposed that working capital or added shareholder value represented financial figures and were indicators for measuring the performance of the supply chain. Working capital measures, such as the cash conversion cycle or cash-to-cash cycle, are performance metrics for calculating how a company managed its capital (Farris & Pohlen, 2008). Priya Datta and Roy (2011) defined return-on-asset (ROA) as the measure of a firm's performance, computed by dividing operating income by total assets. Suarez *et al.* (2013) evaluated the measure of a firm's performance based on calculating the percentage of total sales coming from services due to services being a more profitable long-standing source of revenue than initial product sales (Wise & Baumgartner, 1999). In contrast to previous studies, Suarez *et al.* (2013) found that firms with a focus on products tended to have higher profitability than product firms that relied more heavily on services.

Performance Measures and PSS

Wang *et al.* (2011) gave an overview of the research progress of PSS development and suggested a framework for product service lifecycle management. They defined PSS as a systemof products, services, and a number of network players with required infrastructure that aimed to satisfy customers' needs to co-create value with customers and eventually gain a competitive advantage (Goedkoop *et al.*, 2009).

In Wang *et al.'s* 2011 study, manufacturers provided the result or capability instead of a product to their customers. Manufacturers offered a combination of services and a guarantee of certain results, with the customer paying only for the result. Enterprises gained sustainability, suchas minimizing the environmental impact of consumption by closing material cycles, and according to Wang *et al.* (2011), improved enterprise competitiveness. Overall, customers' needs were better met (Long *et al.*, 2013; Wang *et al.*, 2011).

Ovchinnikov *et al.* (2014) described optimal profit as a measure of economic performance. Product components suppliers and service partners were introduced as PSS configurations by (Long *et al.*, 2013). Enterprises developed PSS by shifting from product-oriented service to customer-oriented service and transforming transaction-based service to relationship-based service. **Figure 3**, adapted from Chun *et al.* (2013) and Wang *et al.* (2011) shows this transformation of service. Wang *et al.* (2011) suggested that the best approach for developing PSS in enterpriseswas to integrate and improve existing technologies rather than building entirely new methods.

Table 9 consolidates various dimensions of performance measures used when analyzing lifecycle affordability, which is adapted from Neely *et al.* (2005). Generic termsof quality, time, cost, and flexibility described the dimensions as performance measures.

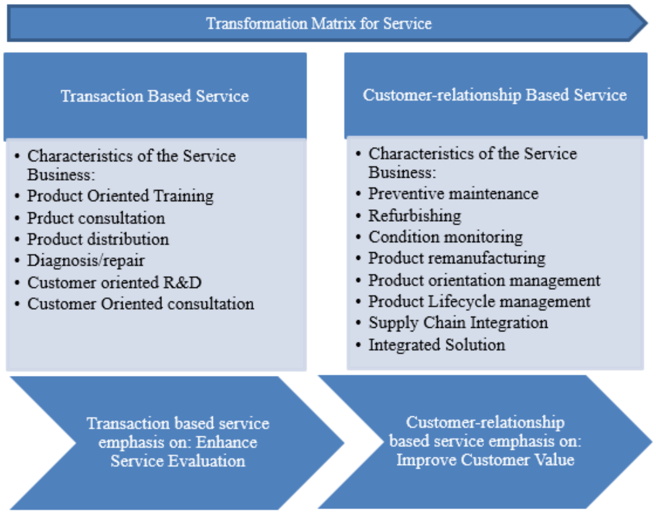

Figure 3 Transformation of service adapted from Chun *et al.* (2013) and Wang *et al.* (2011)

Researchers applied statistical methods to go beyond financial measures within a company. Frontier methods performance measure that use an efficiency score, computed as a firm's distance to the best practice industry frontier and the efficient frontier is estimated by observed inputs and outputs of each firm (Chen *et al*., 2015). In an efficient frontier method, themaximum amount of output can be produced from a specific amount of capital. For each firm, relative efficiency was determined by the difference between the firm's actual output and its estimated best practice (Chen *et al*., 2015).

Table 9 Multiple dimensions of quality, cost, time, and flexibility adapted from Neely, *et al*. (2005)

Quality	Time	Flexibility	Cost
Performance	Manufacturing lead time	Material quality	Manufacturing cost
Features	Rate of production introduction	Output quality	Value added
Reliability	Deliver lead time	New product	Selling price
Conformance	Due-date performance	Modify product	Running cost
Technical durability	Frequency of delivery	Deliverability	Service cost
Serviceability		Volume	
Aesthetics		Mix	
Perceived quality		Resource Mix	
Humanity			
Value			

Chen *et al.* (2015) established frontier methodologies to study U.S. and Japanese automobile industries. Lapré and Scudder (2004) demonstrated frontier methodology in the airlineindustry to study trade-offs between cost and quality. In 2005, Delmas and Tokat used frontier methods to evaluate the performance of an individual firm's relative performance to the best performance in an industry and eventually to explore the challenges of competitive advantage.

Another statistical performance measure was presented when Fallah-Fini *et al.* (2012) introduced the meta-technology ratio, which is the average score of efficiency for either traditionalcontracting or performance-based contracting. The authors suggested that authorities should not rely on only performance-based contracting but instead take a hybrid approach by conveying some features from traditional maintenance contracting to performance-based contracting.

4. CONCLUSIONS AND DIRECTIONS

Firms face challenging decisions when an asset reaches the end of its designed service life. Researchers have studied the challenges associated with extending the retirement date of acapital asset in terms of performance and costs. Jones and Zsidisin (2008) found there was a decrease in performance and an increase in costs when supply chain implications were not clearly defined. Development of supply chain relationships and implementation of supply continuity PBL providers result in inheriting skills, knowledge, and innovation that fulfill requirements for the performance contract, where it reduces costs by having a return on investment.

One way to decrease the lifecycle cost of a product is to invest in process improvement activities by the supplier through contracting. Contracting enables suppliers to invest in cost reduction decisions over the lifecycle of a product. Bernstein and Kök (2009) proposed gradual investment in process improvement instead of a single large investment in technology, which resulted in a radical change. Process improvement requires investment in the form of managerial resources and engineering hours. The U.S. auto industry improved process by adopting lean manufacturing from 1987 to 2002. Value was created and delivered by the management of processes in organizations (Christopher & Ryals, 2014).

This literature review of LCA and management investigated key elements and constructs that the literature identified for this subject. It was concluded that to achieve a higher level of performance, either by cost reduction or profit maximization, constructions should be integrated into the supply chain network. In order to achieve the best outcome possible, the product, organization, and industry should be investigated. A framework for LCA management was proposed (see **Table 10**), connecting literature and context. The framework proposed in **Table 10** has two decisions driven by the literature that explain lifecycle affordability decisions. The first decision is PBL, and the second decision is IBCP. Companies in the third-party sectors are utilizing demand chain ideas through PBL. IBCP, in turn, allows the provider to be rewards for outcome and not provision of a specific activity (Christopher & Ryals, 2014). In other words, PBL can align demand creation and demand fulfillment (Christopher &Ryals, 2014). Through demand management, organizations are capable of reducing the total lifecycle cost by PBL contracting when smart decisions and investments are made in material, technology, and logistics processes, driving down lifecycle cost (Kim *et al*., 2010; Randall *et al*., 2011; Sols *et al*., 2007).

Eventually, PBL can act as a return-on-investment model that develops innovations to achieve long-term performance and affordability (Randall *et al*., 2011). IBCP enables a much closer alignment of supply and demand (Christopher & Ryals, 2014; Smith *et al*., 2010; Stank *et al*., 2012). Through IBCP, the demand chain perspective motivates more accurate forecasting and planning, which leads to a lower lifecycle cost. In addition, IBCP develops a relationship within the supply chain and implements continuity plans as decisions thatfirms may consider extending the lifecycle of capital equipment (Jones & Zsidisin, 2008). This study investigated literature where authors discussed different aspects of the lifecycle of a product and how to manage the LCC and TCO of the product over its entire lifetime. These studies suggested that organizations used lifecycle costing and TCO to examine costs over time.

According to these studies, TCO contained operation costs, quality, logistics, technical advantages, maintenance, inventory costs, lifecycle, initial price, customer related costs, transaction costs, opportunity costs, and obsolescence costs (Ferrin & Plank, 2002). All these costs were associated with various lifecycle stages of a product. Taha, A., and Reynolds, P. L. (2023) studied the role of switching costs between customers and the suppliers (third party-logistics providers), as well as the influence of power exercised wielded by third-party logistics providers over customers, specifically focusing on trust and commitment dynamics in the UK. Their study found that non-coercive power, such as information and reward power, lead to more trust and commitment.

Table 10 Proposed framework for LCA management

	Demand Management	**LCC**	**Affordability**
PBL antecedents and outcomes	Companies in third party service sectors are utilizing demand chain ideas, where the business provider is rewarded for performance outcomes rather than for provision of a specific activity (Christopher & Ryals, 2014)	PBL offers laying out a multi-year contractual framework, typically a firm-fixed price (FFP) contract, that rewards suppliers when they make smart investments in material, technology, and logistics processes which drive down life cycle cost (Kim, Cohen, Netessine, & Veeraraghavan, 2010; Randall *et al*., 2011; Sols *et al.,* 2007)	PBL essentially acts on a return-on-investment model that drives innovations to achieve long-term performance and affordability goals for the customer, while improving overall PBL ecosystem profitability (Randall *et al*., 2011)
IBCP (integrated business continuity planning)	There has been a widespread adoption by business of the principles of Sales and Operations Planning and Integrated Business Planning which is enabling a much closer alignment of supply and demand (Christopher & Ryals, 2014; Smith, Andraski, & Fawcett, 2010; Stank, Esper, Crook, & Autry, 2012)	The demand chain perspective encourages us to inquire about joint forecasting and planning practices, and their impact on forecasting accuracy and costs (Christopher & Ryals, 2014; Ryals & Holt, 2007).	The development of supply chain relationships and the implementation of supply continuity plans are argued as being two practices that firms may wish to consider when extending lifecycle of capital assets (Jones & Zsidisin, 2008)

This research posited that a standard method to evaluate the LCA decision framework doesnot exist. Some measures were more universal than others and appeared in many decision planning activities. Managers implemented different performance measures to evaluate the organization's well-being. This literature review involved different research approaches (i.e., qualitative versus quantitative), data collection methods (i.e., interview survey and content analysis of archival data), and performance measures (i.e., operational efficiency, financial outcomes, and frontier efficiency). Ultimately, empirical research producing reliable and valid findings will be the foundation for managerial decision-making regarding managing capital intensive assets, which will be useful to supply chain managers across various industries.

Companies realize the benefits of delivering exceptional customer service to meet major customer's needs and collaboration across the supply chain. Through PBL and supply chain continuity planning, companies can introduce processes that reduce unreasonable demand. Supply chain collaboration, including information sharing, goal congruence, decision synchronization, joint knowledge creation, incentive alignment, resource sharing, and collaborative communication, all play crucial roles in influencing firm's performance (Nguyen *et al.*, 2022).

5. DISCUSSIONS

This essay provides a framework where two decisions, IBCP and PBL, driven from literature, are decisions that managers in business-to-business relationships can make to reduce the total lifecycle cost and achieve long-term performance affordability.

The successful functioning of the supply chain relies on appropriate contract governance. Contracts are effective governance mechanisms for interfirm exchange (Bai *et al*., 2016). Providing an efficient, sustainable system that is affordable and meets the needs of all customersis the primary goal for an organization. A reliable network will help ensure diversified, value-added performance that supports customer's quality of life, promotes innovation. An integrated approach across governments, industry and other players is critical for addressing challenges. This engagement supports work toward a safe, efficient, affordable, and environmentallysustainable system in the long term.

A review of the literature has found that performance-based strategies were viewed as a more flexible type of contract. MacCormack and Mishra (2015) found that partner integration increased the overall cost of the project. Their results suggested that the optimal choice of contract may not necessarily be a single contract type. They suggested a hybrid type contract that allows projects to balance the relative importance of controlling costs while improving quality. However, there is a need for further research to explore the nuances of how such hybrid contractsmight be designed.

According to Guajardo *et al.* (2012), PBL resulted in product performance enhancement. Their results confirmed that reliability improvement can be achieved under PBL through more frequently scheduled maintenance and better care performed in each maintenance event. The latter impact was accomplished by such activities as conducting more thorough checks leading to better identification of defects, replacement of preemptive parts, and possible product redesign.

6. LIMITATION AND FUTURE DIRECTION

A limitation of the study was that the selected literature was only based on peer-reviewedjournal papers in logistics, business, and supply chain management. Other sources, such as books, conference proceedings, and dissertations were disregarded. This study mapped the key elementsand positions existing in LCA research against cross-disciplinary industries.

The existing literature did not explicitly identify future research directions for LCA. Further, in terms of quantitative measures of LCA, a number of research studies have been done. Many studies performed quantitative analysis. However, the context was limited to a specificindustry such as vehicles and aerospace. Additionally, the current study did not include the subject of sustainability.

Future research should examine qualitative analysis as well as quantitative research on LCA. Creating different scenarios with system dynamics and simulations should be examined. Most of the studies estimated parameters using a specific organization’s data, and the validity of the results should be tested in other empirical contexts. Finally, there should be more studies thatapply theory in their research to explain the relationships and dynamics between different playersin a supply chain network. Further research is needed to apply the study to more organizations and industries.

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