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The effectiveness of performance-based Contracting in the defense sector: A systematic literature review

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Corresponding Author:	Faris Alqahtani Lancaster, UNITED KINGDOM
First Author:	Faris Alqahtani
Order of Authors:	Faris Alqahtani
	Kostas Selviaridis, PhD
	Mark Stevenson, PhD
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Suggested Reviewers:	Finn Wynstra jwynstra@rsm.nl
	Andreas Glas andreas.glas@unibw.de
Response to Reviewers:	

Re: Submission of Revised Manuscript: PURSUP-D-22-00032R2

Dear Professor Carnovale,

Please find enclosed a revised version of our manuscript entitled "The Effectiveness of Performance-based Contracting in the Defence Sector: A Systematic Literature Review" for you to consider further for publication in the *Journal of Purchasing and Supply Management*.

The paper has been revised in response to your feedback regarding its positioning. We would like to express our gratitude to the Associate Editor and the reviewers for their invaluable feedback throughout this journey, which has significantly enhanced the quality of this manuscript. We also appreciate your consideration of accepting our manuscript and wholeheartedly agree with your suggestions. Consequently, we have made changes to the manuscript in accordance with your comments, as follows:

- Title: We have adjusted the title to incorporate your suggestion. The title now reads, "The Effectiveness of Performance-based Contracting in the Defence Sector: A Systematic Literature Review." We changed "performance-based logistics" to "performance-based contracting" but included "defence" to clarify that performance-based logistics (PBL) is essentially a type of performance-based contract (PBC) predominantly applied in the defence industry.
- Abstract: To facilitate a more explicit connection between PBL and PBC, we have added the following statement at the beginning of the abstract: "Performance-based contracting in the defence sector, also known as performance-based logistics (PBL)."
- Keywords: We have included an additional previously omitted keyword: "systematic literature review".
- Introduction: We now more clearly show the connection between PBC and PBL in the introduction by including the following statements: "PBL has prevailed, both in academic literature and practice, as a term referring to the application of PBC in the defence industry. As a concept, PBL is subsumed under PBC; the latter term encompasses all types of contracts that tie payment to results regardless of sector specificities (Hypko et al., 2010; Selviaridis and Wynstra, 2015)". We've also included a reference footnote, which is highlighted in **bold**, to clarify that in the manuscript, we use "PBL" to refer to "PBC" in the defence sector.

All changes have been highlighted in blue. Thank you for your continued consideration of our work; we greatly appreciate the opportunity to submit this revision. If you require any further information, please do not hesitate to contact me.

Yours sincerely,

Faris Alqahtani

[*On behalf of the author team: Faris Alqahtani, Kostas Selviaridis, and Mark Stevenson*]

Response to Editor Comments

Please find enclosed a revised version of our manuscript for you to consider further for publication in the *Journal of Purchasing and Supply Management.* The paper has been revised in response to your feedback regarding its positioning. We would like to express our gratitude to the Associate Editor and the reviewers for their invaluable feedback throughout this journey, which has significantly enhanced the quality of this manuscript. We also appreciate your consideration of accepting our manuscript and wholeheartedly agree with your suggestions. Consequently, we have made changes to the manuscript in accordance with your comments, as follows:

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Highlights

- synthesise previous research via systematic literature review.
- 15 factors influence performance-based logistics effectiveness in defence.
- The influencing factors are connected to either a single or multiple metrics.
- Sustainability and resilience are missing considerations for evaluation.

The Effectiveness of Performance-based Contracting in the Defence Sector: A Systematic Literature Review

Faris Alqahtani, Kostas Selviaridis, Mark Stevenson

Lancaster University Management School, Lancaster, United Kingdom, LA1 4YX.

Corresponding author:

Faris Alqahtani, (f.a.alqahtani@lancaster.ac.uk).

Declaration of interest:

None

The Effectiveness of Performance-based Contracting in the Defence Sector: A Systematic Literature Review

Abstract

Performance-based contracting in the defence sector, also known as performance-based logistics (PBL), is attracting growing interest from operations and supply management scholars. In the defence sector, PBL entails outsourcing weapon system-related maintenance and logistics activities in such a way that it incentivises suppliers to invest in equipment reliability and process improvements at a reasonable cost. Research has advanced our knowledge of how PBL contracts are designed and implemented, but we still have only limited understanding of PBL evaluation issues, specifically PBL effectiveness and its influencing factors. Focusing on the defence context, we address this knowledge gap through a systematic literature review and synthesis of 45 peer-reviewed articles. We identify 15 factors influencing PBL effectiveness, which are grouped into six categories: governance, supply chain management, defence buyer input, innovation, environmental factors, and resources and capabilities. We extend prior research by developing a classification framework of the factors influencing PBL effectiveness. Further, we leverage defence industry-specific characteristics to suggest avenues for impactful future research through a series of propositions, including the need to examine how political factors influence the effectiveness of performance-based contracting in the defence sector. We also suggest that environmental sustainability and resilience requirements should be included when evaluating the effectiveness of PBL contracts and defence contracting more generally.

Keywords: Defense procurement; performance-based contracting; performance-based logistics; performance measurement; systematic literature review

1. Introduction

The defence procurement budget of NATO members has been shrinking ever since the Cold War ended in 1991 (Howard et al., 2016; Humphries et al., 2007; Johnsen et al., 2009; Kleemann et al., 2012). The war in Ukraine – considered the biggest challenge to E.U. security since the Cold War (Al-Hikmat, 2022) – serves as a stark reminder of the importance of defence and military preparedness. After just three months of conflict, many E.U. countries had already announced significant increases in their national security budgets totalling more than €200 billion (Finkbeiner and Van Noorden, 2022). Yet, at the same time, the medium- and long-term economic effects of other disruptive events, such as the consequences of the global COVID-19 pandemic for inflation rates, highlight the importance of innovative procurement strategies capable of delivering immediate defence equipment readiness in a cost-efficient manner. One such strategy is to align the incentives between national defence departments (as buyers) and defence suppliers (Parker and Hartley, 2003) through performance-based contracting (PBC) or, as it is known in the defence sector, performance-based logistics (PBL).

PBL has prevailed, both in academic literature and practice, as a term referring to the application of PBC in the defence industry. As a concept, PBL is subsumed under PBC; the latter term encompasses all types of contracts that tie payment to results regardless of sector specificities (Hypko et al., 2010; Selviaridis and Wynstra, 2015) [1]. PBL entails outsourcing the post-production support of weapons to defence suppliers and linking supplier payments to results (Sols et al., 2007). This can incentivise innovation among suppliers to deliver performance at a lower through-life cost. PBL was first introduced in the U.S. (Sols et al., 2007) as a customer-oriented procurement strategy to address the mismatch between the life-cycle of a weapon system and the useful life of its components (Caldwell and Howard, 2014). It has since been adopted by several other governments.

Prior literature on PBL has addressed a diverse set of themes, including the theoretical underpinnings of PBL (Randall et al., 2010), operations strategies (Datta and Roy, 2011), supply-base management (Datta and Roy, 2013; Kleemann and Essig, 2013), inventory management (Nowicki et al., 2008; Shinde et al., 2019), PBL contract design (Sols et al., 2007), and PBL implementation challenges (Berkowitz et al., 2004; Ng and Nudurupati, 2010), including the hidden costs incurred during contract design and execution (Datta, 2020).

[1] It is noted that while PBL has prevailed as a term (in both the academic literature and practice) to refer to defence PBCs, other terms such as 'contracts for availability' (Caldwell and Howard, 2014) and 'outcome-based contracting' (Ng et al., 2009) have been used to describe the use of performance-based contracts in defence. Consistent with the literature, which uses these terms interchangeably, **we use the term PBL to refer to any PBC or outcome-based contract (OBC) in a defence context.**

Overall, the literature has provided significant insights into how PBL is designed and implemented, including related success factors, enablers, and barriers. However, this body of literature stops short of systematically assessing the effectiveness of PBL, i.e. the ability of PBL to achieve desired performance levels, as reflected in the performance measures specified in a defence contract. Prior research has advanced our knowledge of PBL design and implementation, but to date we know little about *PBL evaluation* issues, specifically: a) the factors influencing PBL effectiveness, where 'influencing factors' refers to all elements that affect, either positively or negatively, the performance of a PBL contract; and, b) how these factors influence the performance measures used to evaluate PBL effectiveness. We therefore ask: *What factors influence the effectiveness of PBL in the defence context, and how?*

To address this research question, we conduct a systematic literature review to synthesise and augment research on factors that influence PBL effectiveness. Systematic literature reviews are suitable for pursuing specific and narrowly defined research questions and for evaluating related bodies of evidence (Durach et al., 2017; Glas et al., 2018; Tranfield et al., 2003). Adopting this approach allows us to organise and integrate fragmented literature insights with respect to salient factors influencing PBL effectiveness. Indeed, the PBL literature is distributed across a diverse set of disciplines and academic journals (for example: the 45 articles we include in our review are distributed across 29 different journals) and research has thus far failed to provide a unified understanding of the effectiveness of PBL as a procurement strategy.

Although previous systematic literature reviews on PBC (e.g., Hypko et al., 2010; Selviaridis and Wynstra, 2015; Holmbom et al., 2014; Glas et al., 2018) have generated important empirical and theoretical insights regarding PBC design and implementation in general (i.e. across sectors), there is hitherto no literature review that focuses on *PBL effectiveness in the defence context* specifically. For example, although Selviaridis and Wynstra (2015) synthesised PBC research in both public and private sector industries, such as healthcare, construction, energy, and business services, the breadth of their study meant they were unable to go into depth on any one industry context. In this paper, we focus specifically on the defence sector – in other words, on PBL defence contracts (rather than on PBC in general) – enabling us to develop a deeper understanding of PBL effectiveness and the influencing factors in this specific context.

The defence context presents four unique characteristics that make PBL contracts theoretically interesting, *vis-à-vis* the broader PBC literature, and that help to delineate novel

implications for service contracting in supply chains. First, defence operating environments entail shifts between peacetime and war operations. The latter trigger radical changes in performance requirements (from cost efficiency to agile maintenance and repairs to ensure weapon availability and readiness) and introduce severe operational and financial risks for PBL providers. Second, defence procurement contracts are agreed and executed through complex government-to-government transactions that are susceptible to export controls for national security and/or political reasons. Changing (geo)political circumstances can influence the performance of PBL contracts when countries collaborating in the production of a weapon system introduce trade restrictions or ban exports of supplies and spare parts, as was the case between Germany and Saudi Arabia (Chazan, 2019). Germany is part of the consortium that built the Eurofighter Typhoon, sold by the giant British manufacturer BAE Systems to Saudi Arabia via Airbus and MTU Aero Engines (Smout, 2019). When Germany boycotted jet and spare part sales to Saudi Arabia for political reasons, it jeopardised BAE's single largest export contract (Smout, 2019), which was reliant on the consortium's approval (Makortoff, 2019). Third, in PBL contracts, defence buyers make government-furnished assets (GFX) and military personnel available to the PBL provider (Ng and Nudurupati, 2010). Unlike in other private sector settings, where outsourcing entails the transfer of employees to the supplier according to national regulations, such military facilities and personnel remain under the defence buyer's control. This increases performance-related risk for the PBL provider when defence buyers do not behave as expected. Fourth, in defence settings there is a reported clash of mindsets and cultures between military personnel on the one hand and the employees of civilian contractors on the other (Datta, 2020). Relatedly, the extent of coordination and teamworking between military officers and civilian personnel is affected by regulations restricting the presence of civilians in conflict zones. All these defence-specific issues introduce distinctive risks and costs that need to be managed to ensure PBL effectiveness; and they further justify the need to focus in this paper on the defence context in isolation.

Accordingly, our literature review on PBL defence contracts allows us to flesh out distinctive factors (e.g. operational, political, cultural, and regulatory factors) and examine how they influence PBL effectiveness. These factors have hitherto been underplayed in prior, cross-sectoral reviews of PBC research (e.g. Hypko et al., 2010; Selviaridis and Wynstra, 2015). In addition, we seek to contribute to the PBL literature (e.g., Randall et al., 2011; Sols et al., 2007) in two ways. First, we synthesise prior PBL research to develop a classification framework of the factors that influence PBL effectiveness, offering insights into the connections between specific factors and particular performance indicators used in PBL contracts. Second, our

framework helps us to identify important knowledge gaps and to propose avenues for future research, for instance regarding the need to further investigate the role of political factors. In line with broader research trends within Purchasing and Supply Management (PSM) scholarship (Knight et al., 2022), we also suggest that a broader evaluation of PBL effectiveness should include resilience and environmental sustainability aspects, which have emerged as increasingly important requirements in defence operating settings. We present our future research suggestions in the form of propositions.

The remainder of this paper is organised as follows. Section 2 defines PBL and the key dimensions of PBL effectiveness. Section 3 then outlines the systematic literature review process adopted before Section 4 presents the findings. Section 5 makes suggestions for future research before Section 6 concludes the paper.

2. Background

2.1 Performance-based Logistics

Conceptually, PBL concentrates on equipment-related after-sales support contracts within the defence sector (Holmbom et al., 2014), while PBC encompasses applications in manufacturing and services and cuts across both the private and public sectors (Hypko et al., 2010; Selviaridis and Wynstra, 2015). PBL is an outsourcing strategy that offers financial and time-based incentives that motivate a supplier to use the knowledge at its disposal to make investments that lead to maintaining or improving weapon system performance (Edison and Murphy, 2012; Randall et al., 2010) while leading to both obsolescence and cost avoidance (Kratz and Diaz, 2012; Randall et al., 2011).

PBL has been adopted by several governments, such as the U.K. (Gansler et al., 2012), Germany (Kleemann et al., 2012), Spain (Sols et al., 2012), Italy (REEM, 2022), Australia (Barber and Parsons, 2009), South Korea (Choi and Suh, 2020), Taiwan (Lin et al., 2013), Saudi Arabia (Reuters, 2009), and Israel (Whitney, 2015). Studies have reported improvements in aspects of performance that are important to governments[2], including a reduction in customer waiting times as well as improved system, sub-system, and component readiness (Kirk and DePalma, 2005) and a cost reduction per unit of performance (Hunter, 2015; Lucyshyn and Rigilano, 2018).

[2] By adopting a through-life approach (i.e. PBL), the UK Strategic Defence Review (SDR) launched a number of significant improvements in 1998 that were intended to enhance both organizations and processes, and that translated into cumulative savings of about £1.4 billion between 2005 and 2008 (Gansler et al, 2012).

PBL has been linked to the servitization and product-service systems (PSS) literatures since it concerns a manufacturer bundling the provision of a product or equipment together with aspects of after-sales service, such as maintenance (Holmbom et al., 2014). Several theoretical lenses have been used in this body of work; for instance, agency theory has been used to explain why outcome-based contracts are considered the optimal form of contract under certain conditions (Datta and Roy, 2013; Kim et al., 2007) and service-dominant (S-D) logic has been used to examine how value is co-created with the buyer in a servitization context (Randall et al., 2010). The latter theory stresses the risks related to service co-production, for instance, when the buyer fails to provide timely information. According to S-D logic, relational governance mechanisms based on collaboration, trust, and information sharing can be used to mitigate such risks (Randall et al., 2010; Randall et al., 2011).

There is no consensus on a single, universal definition of PBL, but the term is prevalent in research focusing on *defence settings* (Batista et al., 2017; Glas et al., 2013). It has three key defining characteristics: "integration between acquisition and logistics for [the] total system life-cycle", "incentives to motivate suppliers", and "performance goals" (Berkowitz et al., 2004, p 258). Even though the first characteristic is used by the U.S. Department of Defence (DoD) to define PBL, in practice, it is the latter two characteristics that are most commonly found in PBL contracts, as the buying organisation links the whole or part of the supplier's payment to desired levels of performance (Selviaridis and Wynstra, 2015). Beyond these three characteristics, PBL contracts are typically implemented in the later years of production (see Datta 2020). Furthermore, we note that a few scholars have used the term PBL to examine PBCs that are applied in a defence setting but that concern services unrelated to weapon system support or pieces of equipment, e.g. catering (Häyhtiö, 2016) and security services (Krahmann, 2017). Our definition of PBL excludes such "service-only" applications since our focus is on contracts for product- or equipment-based services in a defence context.

While the PBL literature focuses on the defence sector, its principles can be applied in other industry settings where the supplier contracts with customers for equipment availability and assumes responsibility for managing spare parts (Sols et al., 2008). For example, in the automobile industry, truck manufacturers such as MAN assume responsibility for maintenance and repairs and are rewarded based on truck availability outcomes. The same principle applies to the civil aerospace industry, where engine manufacturers such as Rolls Royce guarantee engine availability and are compensated based on engine flight hours (Selviaridis and Wynstra, 2015). Manufacturing and construction equipment industries are additional settings where the same PBL principles apply (Hypko et al., 2010). However, as we have already explained in the

introduction, PBL defence contracts also exhibit significant differences to other contexts – and it is these differences that we are particularly interested in.

2.2 PBL Effectiveness

To understand PBL effectiveness, we need to understand what measures are used to evaluate PBL effectiveness, what affects these performance measures, and how. The term 'performance' encompasses results, actions or both (Lebas and Euske, 2006). In this paper, we define a performance-measurement system as a "set of metrics used to quantify both the efficiency and effectiveness of actions" (Neely et al., 1995, p.81). A performance-measurement system encompasses both financial and non-financial metrics (Franco-Santos et al., 2012), and this is also applicable to PBL. The PBL principle is that the customer (i.e. defence) should specify measurable outcomes and outputs (Glas et al., 2018) to a service provider, and then allow the provider to determine the most appropriate processes (the "how") for service delivery. Outputs refer to results directly linked to a service activity or production process (e.g. equipment availability), whereas outcomes concern the value derived by the buyer from a given service or product, e.g. military mission success (Grubic and Jennions, 2018; Selviaridis and Wynstra, 2015). In the context of PBL, outcomes can include 'military mission success' and 'national security'; however, civilian suppliers are unlikely to be able to influence the achievement of such eventual outcomes directly; therefore, PBL contracts are mostly concerned with output- and outcome-oriented performance metrics that are largely controlled by suppliers (Holmbom et al., (2014). It follows that supplier payment in a defence context is linked to performance that is expressed in terms of a mix of outputs and outcomes, such as the availability of a weapon system, the readiness of equipment, and cost-reduction outcomes (Barber and Parsons, 2009).

3. Research Method

We have conducted a systematic literature review following the recommendations made by Durach et al. (2017) and Tranfield et al. (2003). A systematic literature review is different from a conventional literature review. The latter is usually a narrative based on the researcher's familiarity with a given field, whereas the former follows a replicable, scientifically rigorous, and transparent process (Tranfield et al., 2003). In conducting this research, we used two databases: Elton B. Stephens Company (EBSCO) and Web of Science. The former is concerned with business management studies, including OSM research, while the latter covers multiple disciplines, reflecting the diversity of the PBC literature (Selviaridis and Wynstra, 2015). Within the EBSCO database, the following two sources were used based on their

relevance to the business discipline: Academic Search Ultimate, and Business Source Complete. Below, we explain in detail the methodological steps we followed.

3.1 Step 1 – Sample Retrieval Process

Figure 1 illustrates the article-sourcing process. Our search was based on article title OR abstract OR topic, with all papers that contain "defence" OR "defense" OR "military" OR "weapon system*" being considered. We subsequently filtered the results and extracted all those that included PBL and similar themes: "performance-based contract*" OR "performance-based logistics" OR "outcome-based contract*" OR "contract for availability", using the Boolean operator "AND". In this way, we ensured that our sample included any articles that examined PBL or PBC in a defence context, which was the main inclusion criterion for our systematic literature review.

In addition, we limited our sample of articles to those written in English and published between 1994 and 2021. We used this specific timeframe to ensure that we captured all relevant publications starting from the year PBL was first introduced in the defence field, i.e. in 1994 (Randall et al., 2015). We also limited our sample to peer-reviewed journal articles and excluded other publication types such as conference papers. This process resulted in 76 papers being identified. We subsequently eliminated duplicate articles, which resulted in a sample of 56 papers being considered for further analysis.

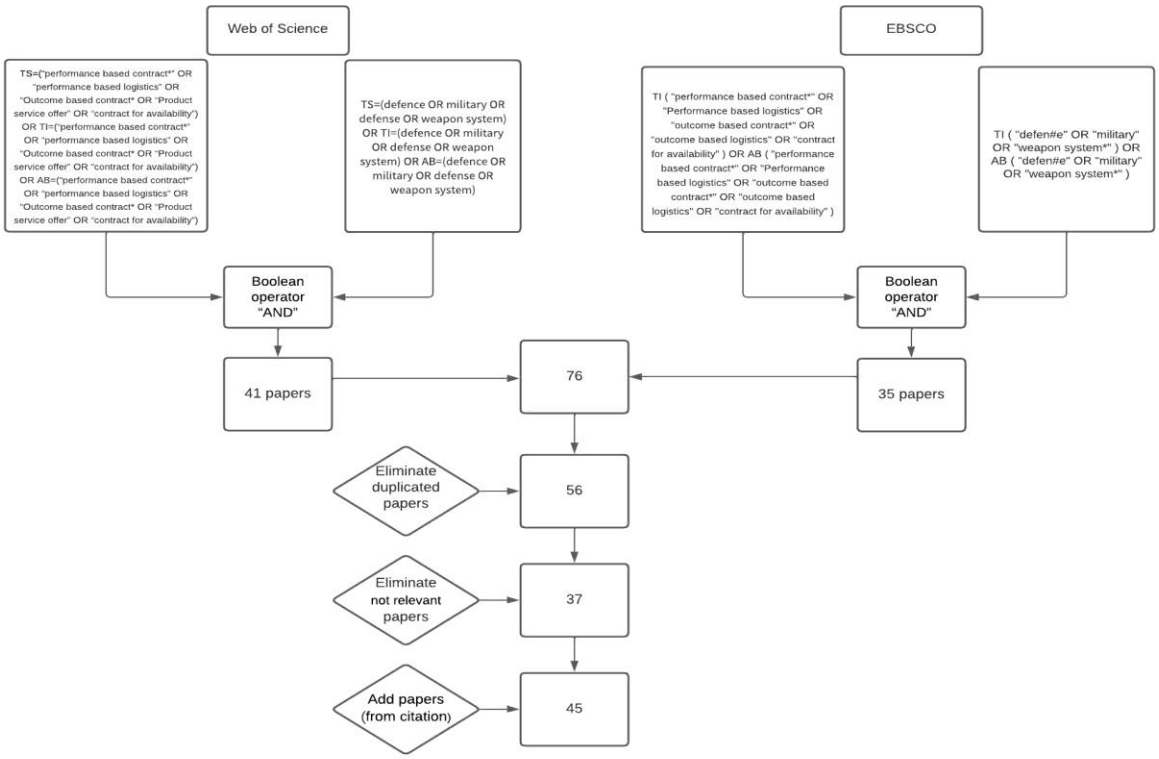

Figure 1: Process of sourcing articles

3.2 Step 2 – Article Screening process

The first step in the article-screening process involved reviewing the 56 remaining papers to exclude papers not relevant to the concept of PBL or PBC in a defence setting. Since not all papers that examine defence performance contracts use the term "performance-based logistics", it was necessary to also include in our search and selection process articles that use the term PBC in order to study output- or outcome-oriented defence contracts. The 56 papers were read in full using the following inclusion criteria: defence PBL or defence PBL design, defence performance measurement, defence PBC outcomes, defence PBL success factors, PBL enablers in defence, PBL challenges/barriers/obstacles in defence, pitfalls and/or strategies. Papers that did not examine one or more of these themes were excluded. Our sample also included PBC literature review papers (Glas et al., 2018; Selviaridis and Wynstra, 2015) because they offer broader insights into themes that are directly relevant to defence settings and to our research purpose, i.e. performance specification, performance measurement, and the factors influencing PBL effectiveness.

This screening process reduced our sample to 37 articles. In a final step, we employed a 'snowballing' approach to identify other relevant articles using lists of references and citations from the retrieved papers. This step helped us to identify a further eight articles

(Berkowitz et al., 2004; Guajardo et al., 2012; Kapletia and Probert, 2010; Randall et al., 2011; Randall et al., 2010; Sols and Johannesen, 2013; Sols et al., 2008; Van Strien et al., 2019), so that our final sample comprised 45 articles (see Figure 1). This step ensured our database of papers was complete and accurate but did not add so many papers that it drew into question the robustness of our overall process. These eight additional papers were not identified in our original search process because defence or defense did not feature in the title or abstract, or the paper was published in a military journal. Appendix A provides details of the journals where the 45 papers were published and highlights the fragmented nature of the field, which it is argued is in need of synthesis.

3.3 Step 3 – Coding and Analysis

In this step, we used three levels of coding and analysis. The first level was to review the literature and identify performance measures and influencing factors using open coding techniques. Our coding was based on the following classification scheme: methods, theories, performance measures and influencing factors. The first author conducted a review of a sample of key studies (i.e. a "scoping study") to identify and include in our initial coding scheme the key factors and performance measures noted in these prior studies. This stage of the literature review process helped in identifying eleven factors and four performance metrics that prior PBL research highlighted as prevalent ones. To facilitate the coding process, we decided to include these eleven factors and four performance metrics as *pre-defined coding categories*. Appendix B shows the initial coding classification scheme and related categories that emerged from the literature review for use in our coding.

The second level used data-extraction sheets (Tranfield et al., 2003) to code and analyse each article in our sample using the classification scheme from the previous step. As a first coding step, 11 papers (representing 25% of the total number of papers) were randomly selected by the third author and independently coded by both the first and second authors. We found 25 disagreements out of 275 possibilities, indicating an inter-rater reliability of 91%. Each disagreement was discussed to resolve any misunderstanding or misinterpretation of the pre-defined factors or performance metrics. We observed that two factors ("contract design" and "contract management") required collapsing into one factor ("formal governance") because they served one purpose (to formally govern the buyer-supplier relationship through contracts). In addition, one other factor ("co-production") was renamed (as "customer input") to increase its clarity, while the factor "politics and regulation" was divided into two separate factors. In addition, we found two performance measures ("supportability" and "maintainability"), which

we included within "maintenance effectiveness". Based on the high inter-rater reliability score, we were confident enough to proceed with the coding exercise, and so the first author then coded all of the remaining papers. During the course of this process, four influencing factors emerged that were not in our pre-defined coding categories. To validate these emerging factors, we performed another inter-rater reliability exercise. Specifically, we chose five papers at random, and, out of 150 coding possibilities, we noted only six disagreements in our coding, i.e. an inter-rater reliability of 96%. These results confirm the validity and reliability of our literature coding approach and findings. The first author then organised the 15 factors into six groups based on axial coding principles. As an example, contract design and management form part of formal governance, while relational aspects are considered to be informal governance; therefore, these aspects were grouped together under the "governance" category. These categories were then discussed by all authors, and governance was renamed "governance of the buyer-supplier relationship" for clarity. Eventually, all minor disagreements among the authors regarding the six higher-order categories were resolved.

The third level was to understand any observed effect(s) for each factor on the performance measures. Each factor was examined against the defence performance measures by the first author using matrix-based data-extraction sheets (Appendix C). This was done by matching each factor with a specific performance measure. For example, the quote "The wrongly set KPIs directed the efforts in the wrong direction resulting in cost escalation across PBC stages for different members" (Datta, 2020, p. 681) was coded as showing a relationship between contractual governance and cost (see Section 4.1.1). Following this process, we identified multiple relationships between factors and performance measurements (a file with our detailed coding results for each article is available upon request). However, it was not possible to connect politics to specific performance measures. For example, the quote from Caldwell and Howard (2014, p. 277) "PCP contracts in oligopolistic markets often involve triadic relationships resulting in coalitions of interest and joint lobbying by two parties against the other" clearly explains that politics affects PBL effectiveness, but it does not specify how. To summarise, Figure 2 illustrates the coding process we followed.

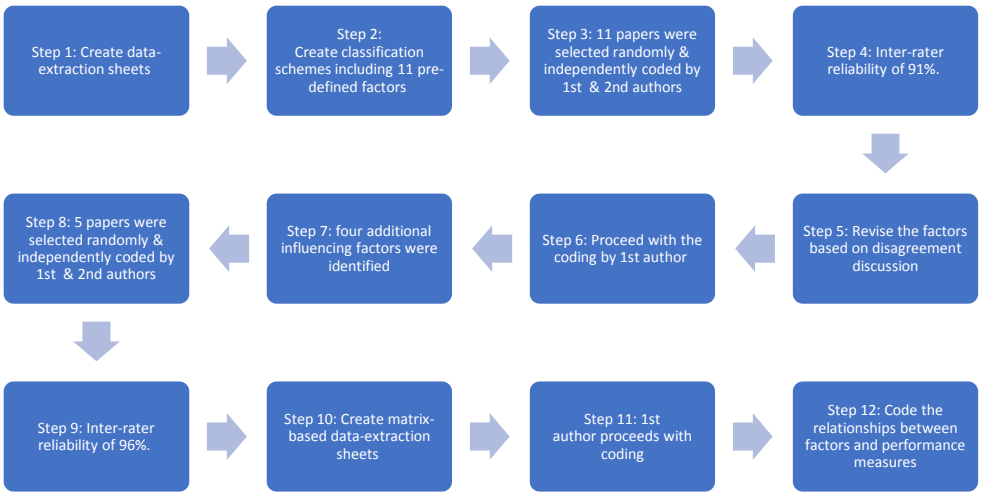

Figure 2: The coding process

4. Findings

The following presents the findings regarding PBL effectiveness and its influencing factors. Appendix D provides a descriptive overview of the PBL literature in terms of research methods and theoretical perspectives employed.

4.1 Key performance measures in defence performance-based logistics

Based on the literature review, we identified four top-level performance measures that defence buyers, and their suppliers, seek to achieve in PBL contracts in defence settings: cost, availability, reliability and maintenance effectiveness (Sols et al., 2007; Datta, 2020). Table 1 defines these four performance measures. Even though these defence KPIs look similar to those used in other contexts, they exhibit certain differences. Specifically, reliability refers to the *military mission's* reliability, which means the system meets its "mission success objectives (percentage of objectives met, by system)" (Defence Acquisition University, 2005, pp.2–5). Military mission objectives vary depending on the system in use; for example, this could be to reach a destination, have a successful missile launch, or any other specified metric (Defence Acquisition University, 2005). These features make reliability metrics in PBL contracts wider in scope that those used in other settings, for instance reliability of manufacturing equipment. In a similar vein, availability performance in the defence context refers to operational availability (Ao), which is a "primary metric used to determine the degree to which a weapon system asset pool is capable of supporting mission requirements" (Kang et al., 2010, p. 56). In other words, operational availability directly influences military mission reliability and success. Moreover, maintenance effectiveness is a combination of metrics, with some being

unique to the defence context. Logistics footprint, in particular, is a metric that refers to government and supplier facilities that can be used to operate a weapon system. Such a metric does not exist in other settings where PBC has been implemented. Supportability and maintainability (of the weapon system) are two other KPIs that are used to evaluate how effective a weapon system component is, and how easy it is to repair. These measures are also prominent in practice as they are used by the U.S. Department of Defence (DoD, 2016) and the Australian Department of Defence (Barber and Parsons, 2009). Overall, the performance metrics used to evaluate PBL effectiveness have some distinctive characteristics that sets them clearly apart from cost and service KPIs used in other industry contexts.

Table 1: Defining the performance measures used in this study

Performance Measures	Definitions
Cost	Total cost associated with achieving weapon system availability, reliability, and maintenance effectiveness.
Availability	Refers to spare parts availability and the operational or utilisation availability of the weapon system.
Reliability	Refers to military mission reliability and the associated weapon system reliability in terms of mean time between failures (MTBF).
Maintenance effectiveness	Refers to logistics footprint, logistics response time, and weapon system maintainability and supportability.

4.2 Factors Influencing the Effectiveness of PBL

Through literature analysis and synthesis, we identified 15 factors influencing PBL effectiveness, which we have grouped into six higher-order categories: a) governance of the buyer-supplier relationship, b) supply chain management, c) defence buyer input, d) innovation, e) environmental factors, and f) resources and capabilities. According to the literature, some of these factors are connected to either a single or to multiple metrics that are used to evaluate PBL effectiveness. Table 2 presents a framework of the 15 factors influencing PBL effectiveness classified according to these six categories. In what follows, we discuss each factor in turn.

Table 2: A classification framework of research on factors influencing PBL effectiveness

		Cost	**Availability**	**Reliability**	**Maintenance effectiveness**
Governance of the buyer-supplier relationship	Contractual governance	Prolonged negotiation, poor incentives and KPIs, and freedom in the SOW can affect cost (Buchanan and Klingner, 2007; Caldwell and Howard, 2014; Datta, 2020; Datta and Roy, 2013; Holmbom et al., 2014; Lin et al., 2013; Randall et al., 2015)		Long contracts can help suppliers improve their products. Poor KPIs and incentives can affect suppliers' willingness to improve reliability (Guajardo et al., 2012; Holmbom et al., 2014; Randall et al., 2012)	
	Relational governance	A lack of trust can lead to a reluctance to collaborate, which can in turn increase the cost. Failures to exchange information can consequently lead to hidden costs (Batista et al., 2017; Buchanan and Klingner, 2007; Datta, 2020; Ng and Nudurupati, 2010)	Sharing information can help to achieve availability targets (Batista et al., 2017; Ng and Nudurupati, 2010)		
Supply chain management	Supply chain integration	Suppliers' involvement through collaboration and knowledge-sharing is key to reducing cost (Datta, 2020; Ng and Nudurupati, 2010)	Integrating sub-suppliers will affect availability since they have the ability to increase spare parts quality (Datta, 2020; Ng and Nudurupati, 2010)	Integrating sub-suppliers will affect reliability since they have the ability to increase spare parts quality (Datta, 2020; Datta and Roy, 2011)	
	Supply-and-demand management	Failing to accurately forecast demand for spare parts can increase budget losses (i.e. cost) (Choi and Suh, 2020)	Failure to accurately forecast demand for spare parts can negatively impact a weapon system's readiness, i.e. availability (Choi and Suh, 2020)		
	Limited number of available suppliers	A limited number of available suppliers can lead to cost increases (Caldwell and Howard, 2014; Doerr et al., 2005; Sols et al., 2007)			
Defence Buyer input		A supplier's inability to understand buyer behaviour affects their profit and eventually PBL cost (Datta, 2020; Datta and Roy, 2013; Ng et al., 2009)	When a defence buyer does not deliver its share (e.g. facilities), the force's readiness (i.e. availability) is affected (Datta and Roy, 2011; Davies et al., 2020; Ng and Nudurupati, 2010)		
Innovation	Maintenance process improvement	Through the use of best commercial maintenance practices, PBL is likely to improve the service and at a lower cost (Randall et al., 2011; Randall et al., 2010)	Improving the maintenance turnaround time will improve the availability of the weapon system (Datta and Roy, 2011; Mirzahosseinian and Piplani, 2011; Patra et al., 2019; Shinde et al., 2019)	Increased repair capacity can lead to improved reliability (Grubic and Jennions, 2018; Guajardo et al., 2012)	Improving the maintenance process can improve maintenance effectiveness (Grubic and Jennions, 2018)

	Technology investment	Investing in technology reduces the risk of disruption, which results in better *cost efficiency* (Datta and Roy, 2013; Randall et al., 2012; Randall et al., 2010)	Investing in technology reduces the risk of disruption, which leads to a higher availability rate (Mirzahosseinian and Piplani, 2011)	Investing in technology reduces the risk of disruption, which leads to a lower failure rate, i.e. better reliability (Grubic and Jennions, 2018)	
	Product redesign	Redesigning high-failure components can reduce the cost of spare parts (Davies et al., 2020; Randall et al., 2011)	Redesigning high-failure components can improve the readiness of a weapon system, i.e. availability (Davies et al., 2020)		
Environmental factors	High-risk environment	Sudden changes in the defence environment affect the cost of operations negatively (Caldwell and Howard, 2014; Datta, 2020)	Uncertainties as a result of war affect availability negatively (Caldwell and Howard, 2014; Davies et al., 2020)		
	Culture	Different mindsets between a buyer and supplier can result in difficulties in transitioning to PBL and incur hidden costs (Datta, 2020)		Culture clashes can hinder teamworking, which will affect reliability improvements (Ng and Nudurupati, 2010; Randall et al., 2015)	
	Regulation	The defence procurement structure (having operational and commercial customers) can increase the time needed to draft a contract, which can in turn accumulate additional costs and affect a supplier's profit (Datta, 2020)			
	Politics				
Resources and capabilities	Learning and knowledge management	When a defence buyer and supplier learn from each other they tend to be more effective in terms of reducing costs (Datta, 2020; Randall et al., 2012; Randall et al., 2010)	Transfer of knowledge from the defence buyer to supplier in the early years of a contract allows the supplier to be proactive and continue to stabilize maintenance activities, which eventually improves availability (Ng and Nudurupati, 2010)		
	Human resources	Failure to send engineers to the battlefield leaves the supplier with extra cost of maintaining equipment where little advanced support is available. (Datta, 2020)			

4.2.1 Governance of the buyer-supplier relationship

Selecting the right mix of governance mechanisms is crucial for attaining and sustaining buyer-specified performance outcomes (Datta and Roy, 2013). Governance of the buyer-supplier relationship comprises two elements, namely contractual governance and relational governance, as discussed below.

4.2.1.1 Contractual governance

Contractual governance encompasses contract design and management. PBL contracts enable defence organisations to reduce life-cycle costs through innovations and cost avoidance (Randall et al., 2010, 2015). An effective contract design depends on factors such as the defence buyer's ability to observe supplier actions, the risk propensity of the defence buyer and/or supplier, and budget constraints (Glas et al., 2013; Kim et al., 2007; Lin et al., 2013). PBL contracts offer lower budgeted costs for a defence buyer, with similar profits for the supplier compared to other payment mechanisms (Lin et al., 2013). Measurable outcomes linked to incentives need to be defined for consistent benefits (Selviaridis and Wynstra, 2015). Selecting competent suppliers is crucial, but the complexity of designing contracts for defence departments caused by legal and regulatory requirements can prolong the negotiation process, which eventually affects supplier planning and *total cost* (Kleemann et al., 2012; Datta, 2020). PBL reduces this complexity by granting suppliers autonomy in production, repair, and management, while necessitating clear contractual specifications and well-defined roles and responsibilities (Holmbom et al., 2014; Datta, 2020). But the precise assignment of responsibilities, scope, baseline, and system utilisation profiles is important to avoid ambiguity and underperformance (Sols and Johannesen, 2013; Sols et al., 2007). Failure to address ambiguity can result in significant underperformance and *financial risks* for the supplier (Berkowitz et al., 2004; Howard et al., 2016; Sols et al., 2007).

Incentives are essential for goal alignment between the defence organisation, the suppliers and supply chain counterparts in PBL (Doerr et al., 2005; Datta and Roy, 2013). Financial incentives, such as bonus payments and penalty clauses, are widely discussed (Datta, 2020; Gardner et al., 2015; Sols et al., 2007). Well-designed financial rewards and penalties based on predefined metrics motivate suppliers to improve *reliability* throughout the contract duration (Sols et al., 2008; Datta and Roy, 2011; Glas et al., 2013). Pain-and-gain-sharing pricing methods encourage *cost reductions* and the proportional sharing of profits and losses based on defence buyer and supplier involvement (Caldwell and Howard, 2014; Datta and Roy, 2013). Time-based incentives (i.e. contract length) impact on market share and supplier

investment in *reliability* and *process improvements* (Gardner et al., 2015; Randall et al., 2012). Designing a short-term contract discourages supplier investment or creativity that might otherwise help to *reduce cost*. Designing KPIs and linking them to payment models is critical for PBL success (Berkowitz et al., 2004; Holmbom et al., 2014). That is, poorly designed incentives and KPIs can lead to performance issues, *cost escalation* and unintended consequences (Selviaridis and Wynstra, 2015; Glas et al., 2018; Datta, 2020). As an example, a poor KPI design may burden the supplier with *hidden costs*, such as extra administration costs. Nevertheless, poor incentives and KPI design affect the supplier's profit, which in turn influences the supplier's decision to invest in *reliability improvements* (Holmbom et al., 2014).

Managing an outcome-based contract is fundamentally different to managing a contract based on a transactional buyer-supplier relationship (Caldwell and Howard, 2014). Without consistent management, and the roles of the defence buyer and supplier being clearly defined, PBL often fails (Howard et al., 2016). Contract management capabilities are imperative and influence performance outcomes (Caldwell and Howard, 2014; Howard et al., 2016; Datta and Roy, 2013) when a prime contractor (i.e. supplier) is working on behalf of a number of sub-suppliers (Datta and Roy, 2013), i.e. the supplier is considered to be a systems integrator in a defence contract connecting multiple system/sub-system suppliers. Performance measurement and reporting also play important roles in determining PBL effectiveness (Barber and Parsons, 2009; Berkowitz et al., 2004; Datta and Roy, 2011; Doerr et al., 2005; Glas et al., 2018; Kang et al., 2010; Sols and Johannesen, 2013). Managing performance measurement can be challenging since the aggregate performance target (e.g. availability) depends on different lower-level targets that also need to be managed effectively (Holmbom et al., 2014). Furthermore, capturing and reporting accurate data enables a decision-maker to make effective and efficient decisions (Glas et al., 2018); however, managing a contract entails high *administration costs*, which may well outweigh the benefits (Selviaridis and Wynstra, 2015).

4.2.1.2 Relational governance

Research has indicated that contractual governance is insufficient on its own for achieving PBL effectiveness; thus, contracts are often complemented by relational governance mechanisms (Datta and Roy, 2013). Relational governance refers to informal, social mechanisms that govern a relationship, such as reputation, information exchange, trust, resource access, and knowledge-sharing (Datta and Roy, 2013; Ng and Nudurupati, 2010). While in a traditional support system, a contract alone may suffice, under PBL, relational mechanisms appear to have

a strong effect on PBL success (Datta, 2020; Datta and Roy, 2011; Datta and Roy, 2013; Randall et al., 2011).

Since PBL entails increased interdependency between defence buyer and supplier, trust plays a vital role in achieving implementation success (Kleemann and Essig, 2013; Ng and Nudurupati, 2010; Randall et al., 2011). A lack of trust can lead to a reluctance to collaborate, which can in turn *increase the cost* of service delivery (Datta, 2020) and hinder innovation (Randall et al., 2015). Most PBL arrangements rely on real-time information-sharing across organisational boundaries in order to learn and to develop an *availability* outcome (Batista et al., 2017; Berkowitz et al., 2004; Datta, 2020; Ng and Nudurupati, 2010). Failing to exchange information can consequently lead to *hidden costs* (Datta, 2020). Furthermore, PBL necessitates interdisciplinary work that requires knowledge-sharing and teamworking (Berkowitz et al., 2004). Teamwork is therefore considered an important factor influencing PBL effectiveness (Barber and Parsons, 2009; Ng and Nudurupati, 2010; Randall et al., 2015).

4.2.2 Supply chain management

The supply chain management category consists of three factors, namely supply chain integration, supply and demand management, and a limited number of available suppliers.

4.2.2.1 Supply chain integration

PBL effectiveness relies on sub-suppliers' capabilities, but sub-suppliers are often not directly linked to the defence buyer contractually (Kleemann and Essig, 2013). The defence supply base accounts for most of the supply chain costs and plays a significant role in determining technical upgrades, repairs, and obsolescence management (Datta and Roy, 2011). Since PBL relies on innovation (based on reliability and process improvements) to reduce the cost baseline, sub-suppliers' involvement through collaboration (Batista et al., 2017; Datta and Roy, 2011; Ng and Nudurupati, 2010) and knowledge-sharing (Datta and Roy, 2013; Randall et al., 2010) is key to *reducing cost* and mitigating the impact of *hidden* costs (Datta, 2020). This includes setting up effective information-sharing processes, improving visibility along the supply chain, explaining long-term objectives, and creating inclusive performance-based incentive systems that also reward good performance of the supply base (Datta, 2020). *Availability* and *reliability* are also affected by supply chain integration, since it is the sub-suppliers that have the ability to increase spare parts quality (Datta and Roy, 2011), which in turn affects availability (Datta, 2020).

PBL seeks to align goals and interests along the supply chain and to consolidate the supply chain network (Randall et al., 2010). Even though sub-suppliers' interests may differ from those of suppliers, they seek to align their goals with those of their downstream counterparts in order to drive performance improvements (Kleemann and Essig, 2013). In the PBL process, a sub-supplier profits from product faults whereas a supplier is paid based on fewer products failing (Datta and Roy, 2011). This issue raises a challenge for the supplier to restrict the number of faulty items (Caldwell and Howard, 2014). This can be achieved through a three-way incentive split (Caldwell and Howard, 2014), at least for major sub-suppliers (Kleemann and Essig, 2013). Not engaging with sub-suppliers can result in escalating *costs* and performance losses in the delivery and adaptation stages (Datta, 2020).

4.2.2.2 Supply and demand management

Accurate forecasting of spare parts can help to reduce military budgets (i.e. *cost*) and improve *military operation utilisation*, i.e. *availability* (Choi and Suh, 2020; Glas et al., 2013; Van Strien et al., 2019). Failing to accurately forecast demand for spare parts can increase budget losses (i.e. *cost*) and negatively impact on weapon system readiness, i.e. *availability* (Choi and Suh, 2020). The visibility of frontline usage is an issue for spare-parts demand accuracy (Datta and Roy, 2011). An unexpected rise in demand as a result of the complexity, dynamism, and volatility of the military environment is another issue for demand accuracy (Datta and Roy, 2013; Davies et al., 2020; Glas et al., 2013) that affects a supplier's profit (Datta and Roy, 2013). Moreover, PBL entails reliability and process improvements*;* therefore, pre-PBL demand cannot be relied upon since usage patterns change, meaning it is important to forecast future difficulties (Ng and Nudurupati, 2010). A new and less mature weapon system will have few or no historical data, which may affect the accuracy of demand forecasting (Van Strien et al., 2019). Furthermore, since PBL has a long lifecycle, the supply of spare parts is mostly affected by technological progress, monopoly and oligopoly markets, suppliers' bankruptcy, and obsolescence (Glas et al., 2013; Sols et al., 2012).

In addition, fleet size can also affect a supplier's ability to deliver the desired outcomes effectively (Guajardo et al., 2012). For example, if the defence buyer owns a large fleet, the supplier will be in a better position to manage inventory *efficiently* (Guajardo et al., 2012). However, the fleet size may also affect usage rates and usage behaviour, which can in turn impact the supplier's ability to deliver *availability* at a reduced *cost* (Patra et al., 2019).

4.2.2.3 Limited number of available suppliers

The defence sector has undergone waves of privatisation, followed by mergers and acquisitions, creating a market with only a few sellers and even fewer defence buyers – with only central governments acting as buying organisations and project commissioners (Caldwell and Howard, 2014; Doerr et al., 2005). Moreover, by virtue of the need for governments to maintain their sovereignty in defence capabilities and invest in related skills and industrial expertise, the number of suppliers operating in any given country is *de facto* limited (Howard et al., 2016). A limited number of available suppliers can lead to restrictive trade practices, such as cartels, *cost rises*, and restricted production (Caldwell and Howard, 2014). Moreover, the defence industry is affected by infrequent demand patterns (e.g. one aircraft carrier to be built every decade), which leads to the loss of skills and knowledge, and in turn affects the ability to meet future production requirements (Caldwell and Howard, 2014). Furthermore, limited sourcing options can create supplier dependency, which can in turn lead to weak supplier incentives to improve the system and *reduce life-cycle costs*, making supplier switching difficult when incumbent suppliers under-perform (Holmbom et al., 2014; Howard et al., 2016). Furthermore, the absence of price benchmarking can lead to defence buyers paying more than they should (Doerr et al., 2005). Overall, the structure of the defence supply market (nationally and internationally) and its operating principles can affect PBL effectiveness in terms of cost performance.

4.2.3 Defence buyer input: facilities and military personnel

PBL entails the defence buyer making government-furnished assets and materials (GFX) and personnel available to the PBL provider (Ng et al., 2009). This means that the supplier depends on the defence buyer's inputs (e.g. material resources and information) to create value and deliver a desirable military outcome (Ng and Nudurupati, 2010). If the buyer fails to deliver on responsibilities specified in the contract, such as personnel or facilities, the supplier *incurs costs* that are additional to the agreed budget in order to deliver an acceptable outcome, which in turn negatively affects the supplier's profit and PBL *cost* (Batista et al., 2017; Datta, 2020; Datta and Roy, 2013). This impacts on the supplier's profits and both the force's readiness (i.e. *availability*) and *budget* (Datta, 2020; Datta and Roy, 2013). In addition, a supplier's inability to understand buyer behaviour affects their profits and, eventually, PBL *cost* (Datta, 2020). The supplier offers equipment, but this is used by the defence buyer to achieve the desired functionality and value (Ng et al., 2013). Changing patterns in the defence buyer's product use (e.g. extra flying hours or equipment misuse) can disrupt the supplier's planning, especially if

the supply base is not involved (Datta, 2020), which in turn affects PBL *cost* (Datta and Roy, 2011). When a supplier is unable to understand a defence buyer's behaviour, PBL is negatively affected and *hidden costs arise* (Datta, 2020). In order to reduce supplier system variability, intervention in the defence buyer's system is needed (Batista et al., 2017), including by specifying clear operational boundaries (Ng and Nudurupati, 2010; Sols et al., 2007).

4.2.4 Innovation

The innovation category covers three factors, namely maintenance process improvement, technology investment, and product redesign.

4.2.4.1 Maintenance process improvement

Through the use of best commercial maintenance practices, PBL is likely to increase weapon system *availability* and *reliability* at a lower *cost* (Nowicki et al., 2008). In order to have an effective PBL arrangement, the supplier makes investments that concentrate on component *reliability* (Mirzahosseinian and Piplani, 2011; Randall et al., 2010; Settanni et al., 2016), efficient repairs (Datta and Roy, 2011; Shinde et al., 2019), logistics and *maintenance capabilities* (Nowicki et al., 2008), and system redesign (Randall et al., 2011). As an example, more frequently scheduled maintenance and improved care can lead to *faster repair times*, better *availability* (Patra et al., 2019), and improved equipment *reliability* (Guajardo et al., 2012), which can eventually result in *cost* reductions (Howard et al., 2016) and improved affordability (Randall et al., 2010). However, requiring more time to repair parts at the depot is likely to have a negative impact on availability targets (Patra et al., 2019).

4.2.4.2 Technology investment

Investing in technology reduces the risk of disruption, which leads to a higher *availability* rate, a lower failure rate, i.e. *reliability* (Mirzahosseinian and Piplani, 2011), and eventually greater *cost efficiency* (Datta and Roy, 2013; Randall et al., 2012). As an example, investing in big data analytics (e.g. sensors and systems that generate vast amounts of data during flight operations) helps to reduce random, unexpected spikes in demand, absorb variety in emergent needs, and improve product performance, *availability*, and maintenance efficiency. Increasing automation and facilitating fast communication can have a considerable impact on suppliers' profits and positively affect *reliability*, availability, maintenance and *cost outcomes* (Datta, 2020; Datta and Roy, 2013; Davies et al., 2020; Grubic and Jennions, 2018; Mirzahosseinian and Piplani, 2011; Randall et al., 2012). Investing in technology is considered to be a form of

essential risk mitigation that leads to PBL effectiveness in terms of improved *availability* (Grubic and Jennions, 2018; Mirzahosseinian and Piplani, 2011; Randall et al., 2012). Moreover, improving *reliability* through upfront investment helps suppliers to engage in *cost avoidance* activities, which can translate into extra profits (Randall et al., 2015; Randall et al., 2011; Randall et al., 2010). For example, investing in additive manufacturing (3D printing) increases flexibility, which can be a solution to dealing with varying defence buyer requirements (Davies et al., 2020).

4.2.4.3 Product redesign

Although a weapon system is made to serve for decades (Berkowitz et al., 2004), its sub-systems and components are not (Classi et al., 2018). This is because sub-systems and components are more likely to be affected by use-related wear-and-tear, obsolescence and the advent of new technologies (Classi et al., 2018; Sols et al., 2012). Therefore, effective planning for product redesign is considered essential for a weapon to remain relevant, sustainable and cost-effective throughout its lifecycle (Classi et al., 2018). Investing in product redesign to accommodate variation or improve equipment is one solution to meeting *availability* targets. If the weapon system goes into maintenance due to a failed component, the *availability* target may be affected, but by extending the mean time between failures as a result of a product redesign or reengineering, *availability* targets can be achieved. In addition, extending the mean time between failures by redesigning high-failure components can also reduce spare parts consumption, cutting both maintenance and spare parts availability costs, which in turn helps to *reduce the total cost of ownership* (Davies et al., 2020). Yet, product redesign activities often add complexity to the product architecture (i.e. difficulties in integrating a new design into the product architecture), which may in turn affect through-life PBL *costs* (Davies et al., 2020).

4.2.5 Environmental factors

Environmental factors pertain to the high-risk operating environment of defence (i.e. operations during wars) as well as to cultural, political and regulatory factors.

4.2.5.1 High-risk operating environment

The defence environment includes both peacetime and wartime. During an engagement in active conflict (i.e. war), supply conditions are not aligned with the best practices observed during peacetime. Wars affect the supply chain and logistics pattern, and they change the balance of performance priorities from a focus on cost efficiency to a concern for equipment

availability and supplier responsiveness. Such change comes at an *additional cost* (Caldwell and Howard, 2014). In addition, uncertainty in military requirements increases (e.g. product redesigns to respond to evolving needs, poor demand visibility, etc.), and *availability* becomes a crucial metric for success (Caldwell and Howard, 2014; Davies et al., 2020). This change in requirements may affect a supplier's ability to deliver outcomes (Doerr et al., 2005). Defence also operates in different geographical regions, which may inhibit the supplier's ability to adapt and operate effectively (Datta and Roy, 2011). Furthermore, high-risk environments can affect a supplier's ability to provide appropriately skilled people (see Section 4.2.6.2).

4.2.5.2 Culture

Organisational culture has been discussed in the literature as an obstacle to PBL effectiveness. PBL entails a shift in mentality away from military personnel having superiority in the supplier-buyer relationship, as the supplier becomes the design authority (Datta, 2020; Ng and Nudurupati, 2010). This change might be seen as a threat to military pride (Datta and Roy, 2011) and, on some occasions, it has led to cultural clashes (Datta, 2020) that affect the execution of PBL contracts. This mindset (of the supplier or defence buyer) may hinder the effective transition to, and adoption of, PBL, which leads to *hidden costs* (Datta, 2020). Moreover, the supplier can suffer from the attitudes of military personnel, such as their perceptions of maintenance and how they document it, which leads to uncertainties around the estimation of human resource requirements (Datta, 2020; Datta and Roy, 2011; Ng et al., 2009). Furthermore, the relationship between commercial and military interests can be harmed by a culture of blame (Datta and Roy, 2011). In addition, a culture of "if in doubt send it back for repair" results in *extra cost* for PBL (Datta and Roy, 2011). These cultural clashes may add *hidden costs* to PBL execution, thereby reducing its effectiveness (Datta and Roy, 2011).

Organisational culture can also negatively affect *reliability* through preventing teamworking and knowledge-sharing (Ng and Nudurupati, 2010), which in turn hinders *reliability* improvements (Randall et al., 2015). Adopting and implementing PBL requires changes in organisational structures and budget allocation, which leads to changing the organisational culture (Berkowitz et al., 2004; Kleemann et al., 2012; Sols and Johannesen, 2013). This change in structure may affect organisational members within both supplier and defence buyer organisations, whereby they find it difficult to reconcile the change (Ng and Nudurupati, 2010). Overcoming this challenge often relies on a shift in employees' mindset and a transformation in organisational leadership (Batista et al., 2017; Datta, 2020; Randall et al., 2010).

4.2.5.3 Regulation

PBL is a contracting strategy that follows public procurement procedures with special characteristics, e.g. prohibiting close relationships with suppliers, and an emphasis on transparency and accountability, sometimes at the expense of efficiency (Randall et al., 2011). PBL usually also involves multiple defence buyers: a commercial buyer to represent the public organisation and draft the contract, and an operational buyer who is the actual user of the equipment (Datta and Roy, 2011). This procurement structure can increase the time needed to draft the contract, which can in turn accumulate additional *costs* and affect the supplier's profit (Datta, 2020). The time to draft a contract is extended further when the operational buyer's requirements change during the design phase. Moreover, in certain cases the commercial buyer may have limited understanding of the operational buyer's actual requirements, which can affect how contractual performance is specified and evaluated (Datta, 2020).

Furthermore, budget allocation rules can have a bearing on successful PBL implementation (Sols and Johannesen, 2013). Government regulations and related constraints on budget allocation can affect the length of a contract (Randall et al., 2010). For example, U.S. defence regulations stipulate that a contract length cannot exceed five years (Gardner et al., 2015). These regulatory requirements can, in the eyes of a supplier, be restrictive in that they discourage suppliers from making a large-scale investment in sustainably reducing *costs* (Gardner et al., 2015; Randall et al., 2010). Moreover, other hampering factors can arise from changing legal and regulatory requirements. For example, regulatory agencies such as the Federal Aviation Administration have imposed stringent requirements on component approvals due to the safety-critical conditions in which aerospace and defence firms operate (Davies et al., 2020).

4.2.5.4 Politics

Defence operations are inextricably linked to national defence agendas, which can vary depending on political and geopolitical considerations. For example, the U.K. and France had an in-principle agreement to build an aircraft carrier with a PBL contract set to run for the length of the product life-cycle, which would have worked in the best interests of both nations. However, political considerations extended the negotiations considerably, which led to the U.K. government withdrawing and building the carrier by itself (Howard et al., 2016).

Equally important is the fact that PBL usually involves a relationship consisting of multiple customers within the defence buying organisation (i.e. procurement agency *vs*. military end-users of the equipment) and a supplier-side alliance including a system integrator

(PBL provider) and multiple manufacturers (Howard et al., 2016). The alliance of manufacturers can span multiple countries, each having their own political agendas and interests. The earlier example of Germany banning exports of the Eurofighter jet to Saudi Arabia is illustrative in this regard. In addition, during the development phase, an alliance of manufacturers will typically lobby against each other to win the post-production support contract (i.e. PBL) (Caldwell & Howard, 2014). Moreover, when the weapon system is delivered to the operational customer, the responsibility for managing the relationship is transferred from the commercial buyer (e.g. procurement agency) to the operational customer (e.g. navy). When this change occurs, the PBL holder may exploit the structural gaps left by the commercial buyer (seeking profits), which can negatively impact PBL (Howard et al., 2016).

4.2.6 Resources and Capabilities

This category consists of two factors, namely learning and knowledge management, and human resources.

4.2.6.1 Learning and knowledge management

Knowledge is a source of competitive advantage that contributes to value creation for the defence buyer (Randall et al., 2010). The ability of the supplier to exploit knowledge to create value and innovate can result *in cost avoidance* and mutual benefits (Nowicki et al., 2018; Randall et al., 2012). PBL harnesses knowledge along the supply chain and among inter-organisational teams to improve supplier network-level decisions (Randall et al., 2015; Randall et al., 2010). For example, the transfer of military operations-specific knowledge from defence buyer to supplier in the early years of a contract allows the supplier to be proactive and continue to stabilise maintenance activities, which eventually improves *availability* (Ng and Nudurupati, 2010), whereas imprecise knowledge of requirements at the design stage can lead to *hidden costs* (Datta, 2020). Moreover, when the defence buyer and supplier learn from each other they tend to be more effective in terms of *reducing costs* (Datta, 2020). A buying organisation that learns how to increase its supplier's engagement is likely to *reduce PBL costs* (Datta, 2020). Defence buyers can also learn from previous PBL contracts *to increase cost efficiency* benefits in subsequent contracts (Datta, 2020; Randall et al., 2012; Randall et al., 2015).

4.2.6.2 Human resources

A lack of skilled personnel is a major challenge for any PBL contract (Barber and Parsons, 2009). This is especially the case during periods of conflict. As a mission can be dangerous, only trained soldiers can be sent into conflict zones (Glas et al., 2013). Thus, a lack of skilled engineers and workers may diminish PBL effectiveness in wartime. Meanwhile, in dangerous conflict settings, the participation of civilian personnel has implications under United Nations law and can endanger the well-being of employees (Holmbom et al., 2014), which eventually leads to *higher costs* when risks are taken. It also affects the supplier's budget planning since serving the customer during wartime in unchartered territories burdens the supplier with *extra costs* to maintain equipment where little advanced support is available (Datta, 2020).

More generally, competence in managing relationships, and an ability to convert knowledge into value whilst working as a team are seen as key factors driving effectiveness (Ng et al., 2013; Ng et al., 2009; Randall et al., 2015; Settanni et al., 2016). Moreover, skilled leadership positively influences PBL effectiveness (Randall et al., 2011). A supplier may need to use leadership skills to improve supply chain decisions that create value for the defence buyer (Randall et al., 2010). Leaders who accept new ideas, empower their employees, recognize opportunities, influence system design, and encourage entrepreneurial behaviour appear to play a key role in effective PBL implementation (Randall et al., 2011).

5. A Future PBL Research Agenda

In addition to developing a classification framework on the factors influencing PBL effectiveness, our study identifies several important knowledge gaps that OSM scholars could address through further research. Below, we make four key suggestions for future research that build upon and extend the proposed framework (Table 2). Specifically, we draw attention to certain under-explored factors and their relationship with PBL effectiveness; we argue for the salience of sustainability and resilience performance outcomes as additional dimensions of evaluating PBL effectiveness and defence contracting more generally; and stress an opportunity to use defence context specificities (namely, the transition between peace and war periods and the stark differences in performance priorities linked to these periods) to increase our understanding of how defence buyers and suppliers learn to design and implement performance-based contracts over time.

5.1 Suggestion 1 - Unexplored Factors and Their Relationship with PBL Effectiveness

5.1.1 Incentive alignment along the supply chain: effects on reliability and maintenance effectiveness

The essence of PBL is to improve the readiness of a weapon system by using manufacturers' knowledge to improve reliability, reduce the mean time between failures (MTBF), improve the service process and eventually reduce costs (Randall et al., 2010). Incentives play an important role in motivating suppliers to invest in improvements, but the PBL literature has focused on examining how incentive alignment impacts reliability and maintenance effectiveness in the context of dyadic relationships – a wider supply chain perspective is largely missing.

The aim of incentive alignment is to allocate risks and profits fairly between the parties involved (Datta and Roy, 2013). However, PBL often entails a triadic supply relationship that includes government defence as the buyer, the prime (i.e. supplier) as the system integrator, and near-prime(s) (i.e. Tier 1 suppliers) as (sub)system or component supplier(s); therefore, designing incentives that align goals with respect to reliability and maintenance effectiveness improvement along the supply chain is a major challenge, and misalignment can affect profit and contract attractiveness (Datta and Roy, 2013). Furthermore, while PBL incentivises the supplier to achieve fewer errors, a reduced number of quality defects means less revenue for sub-suppliers (Caldwell and Howard, 2014). In addition, there is, all-too-often, a lack of visibility between the defence buyer and sub-suppliers, where the supplier (i.e. system integrator) has a traditional contract with its sub-suppliers (Datta and Roy, 2011). These observed challenges raise questions concerning how incentives can be designed to influence sub-suppliers, who have the ability to improve the quality of spare parts. Therefore, we propose:

Proposition 1a: *Aligning incentives across the supply chain increases the likelihood of improved PBL effectiveness in terms of reliability and maintenance effectiveness.*

To date, only a few studies have examined PBL incentive alignment along the supply chain (e.g. Datta and Roy, 2013; Kleemann and Essig, 2013). There remains a lack of understanding about how PBL incentive alignment along the supply chain influences reliability and maintenance effectiveness outcomes. A future study could, for example, shed light on the optimal incentive model that fosters product (quality) and (service) process improvements using a case study approach. This could include multiple or single cases of defence settings (i.e. of triadic relationships) to understand and explain how incentive alignment along the

supply chain affects reliability and maintenance effectiveness. Non-defence PBC literature may also prove useful for extending this line of work further (e.g. Nikulina and Wynstra, 2022).

5.1.2 Politics and PBL effectiveness

Politics is a factor that the literature has identified as influencing PBL effectiveness in broad terms (see Caldwell and Howard, 2014; Howard et al., 2016). PBL contracts in oligopolistic markets often involve triadic relationships, as mentioned above. Yet, previous research has stopped short of explaining how politics influence PBL effectiveness at a more granular level (Table 2). A weapon system is usually built by a coalition of OEMs. When a defence buyer decides to contract based on PBL, the PBL provider will usually be one of the weapon system OEMs. According to the literature, this situation "results in coalitions of interest and joint lobbying by two parties against the other" (Caldwell and Howard, 2014, p. 277). This coalition of alliances will negatively affect performance. Moreover, most weapon systems are made by an alliance of OEMs, where each OEM is situated in a different country. The cost of PBL is reduced when there is teamworking and information-sharing across the supply chain, while reliability is improved when sub-suppliers (i.e. other OEMs) are integrated with the supplier. However, geopolitical factors might restrict teamworking and information sharing, thus increasing the costs of weapon system post-production support. For example, when the UK exited the European Union, coordination efforts between the UK and Europe's defence and aerospace industries were negatively affected (Oleksiejuk, 2020). We thus propose:

Proposition 1b: *A weapon system that is manufactured by a group of OEMs originating in different countries with divergent political interests and goals increases the likelihood that the PBL provider will incur additional costs, thereby reducing PBL effectiveness.*

One promising opportunity for further empirical research is to empirically study PBL in the context of an alliance between UK and European manufacturers, and to explore alliance dynamics and their effects on PBL effectiveness post-Brexit. Case-based research of incidents where producer countries restrict exports of materials and spare parts for geopolitical reasons would also be relevant in this respect.

5.1.3 Foreign exchange and PBL effectiveness

The aforementioned Typhoon Eurofighter was developed and manufactured by several companies based in four different countries (EUROJET, 2022); and the resulting jet was sold

to several other countries outside the countries of manufacture. Such a business raises questions about the effectiveness of PBL when the supplier is based in a foreign country, given that payment may be made based on the supplier's currency. This can affect and be affected by the monetary system of the host country, especially when the government of the host country has a fixed exchange rate to a hard currency (e.g., Saudi Arabia has a fixed exchange rate to the U.S. dollar). This can in turn negatively influence the country's financial reserves, even if it lowers the cost of post-production support, and thus reduces the effectiveness of PBL. Moreover, the recent drop in the pound sterling and the euro against the U.S. dollar also raises questions about how PBL cost measurement will be affected if payments entail currency exchange. Thus, we propose:

Proposition 1c: *A PBL contract between a buying government and supplier that involves using different currencies for financial transactions increases the likelihood of the buyer incurring higher PBL costs, thereby reducing PBL effectiveness.*

In-depth case studies of PBL contracts between buyers and suppliers originating in countries that use different currencies are suitable to enable a better understanding of how foreign exchange affects PBL effectiveness.

5.2 Suggestion 2 – Exploring the effect of incentive alignment across the supply chain on supply chain resilience

In a defence setting, resilience involves the ability of prime contractors and their supply chains to respond to crises and secure the continuity of supply and related service support chains. It is somewhat surprising that resilience is not discussed in a PBL context from the perspective of desired performance, especially given that defence entails war (an inherently disruptive state) as part of its core operation. For example, the recent conflict between Russia and Ukraine has affected the microchip industry since half of the world's production of neon (a key ingredient for making chips) is in these two countries (Alper, 2022). Such disruption has inevitably affected prime defence contractors and their supply chains (both product and after-sales service supply chains) as chips are a vital component in any modern weapon system (Shivakumar and Wessner, 2022). The literature pays little attention to evaluating, managing, and strengthening supply resilience in PBL settings or to considering the relationships between the identified factors (e.g. resources and capabilities) and supply resilience. Although maintenance effectiveness (logistics footprint and time to repair) can be argued to be a performance measure

for assessing resilience, the literature fails to explain the effect of supply chain resilience strategies (Tukamuhabwa et al., 2015) on PBL effectiveness.

Accordingly, we submit that, in a defence context, which requires a rapid shift from cost efficiency to responsiveness following the onset of war, building a resilient supply chain is imperative. Evaluating, managing, and strengthening resilience requires upfront investments that will improve the maintenance process and entails redesigning high-failure products to create more resilient suppliers and supply chains. However, resilience depends on the supply chain, the support chain and the efforts that are made by suppliers to motivate sub-suppliers to improve systems congruency, risk management and shared understanding of outcomes. This necessitates aligning incentives along the supply chain in order to improve supplier resilience. Accordingly, we propose:

Proposition 2: *Incentive alignment between the buyer, supplier and sub-suppliers increases the likelihood that a supplier is able to meet required performance outcomes despite encountering disruption, thereby ensuring PBL effectiveness.*

Qualitative research can be employed to explore resilience in a PBL context. In-depth investigation could also reveal how PBL effectiveness can be extended to include further resilience-related metrics. Moreover, several theories could be employed; for example, the supply-chain resilience literature indicates that Complex Adaptive Systems (CAS) theory is a potential theoretical lens (Tukamuhabwa et al., 2015) while agency theory may also be a potential tool for investigating the above proposition. There is also an opportunity to study the effects of Covid-19 to better understand how disruptive events affect the ability to maintain performance under a PBL arrangement and support defence departments and defence suppliers in understanding how they might be able to emerge from the pandemic stronger than before.

5.3 Suggestion 3 – Exploring the relevance of environmental sustainability for PBL effectiveness and defence contracting in general.

Prior research has evaluated PBL effectiveness against four main performance measures (Section 2.2). We have observed that, in practice, defence departments and their suppliers have started to pay attention to environmental sustainability and begun to seek to evaluate the efforts that are made to make defence operations "greener". For example, the U.K. Ministry of Defence (MoD) has started to consider including environmental sustainability metrics in supplier performance evaluations, including targets for reduced or more efficient use of

materials and energy (UK MoD, 2018). Despite these developments, academic research has overlooked environmental sustainability as a relevant performance dimension in defence contracting in general, and in PBL contracts in particular.

PBL is considered by many scholars to be a Product-Service System (PSS) (Baines et al., 2007), which means that PBL contracts can promote environmentally sustainable goals, principally by motivating suppliers to reduce their use of raw materials, spare parts and other service-related supplies. For example, PBL can improve the reliability of a weapon system, which will in turn extend product life cycles and reduce the use of spare parts and production materials. In this sense, PBL has the potential to become a more environmentally sustainable choice for the post-production support of weapon systems. Future research should address the relevance of certain aspects of environmental sustainability (e.g. reduction in resource use) and examine whether there are any tensions or trade-offs involved between achieving sustainability targets on the one hand, and ensuring availability, readiness and cost targets on the other. Another interesting avenue for further research is to investigate how and under what conditions contractual KPIs and incentives motivate suppliers to expend effort in contributing towards the environmental sustainability targets of defence departments. We therefore propose:

Proposition 3: *Introducing efficient resource use requirements into defence contracts increases the likelihood that suppliers will invest in extending the useful life of a weapon system, thereby improving PBL effectiveness whilst simultaneously meeting the environmental sustainability objectives of defence buyers.*

Since this topic has received little academic attention to date, any investigation into how sustainability relates to PBL effectiveness requires exploratory research of a qualitative nature. The PSS literature can inform studying sustainability outcomes in PBL, while agency theory may again be a useful theoretical lens for examining how the principal (i.e. defence department) can incentivise agents (suppliers) to work towards environmental sustainability objectives. This suggestion is in line with calls to examine how PBC can contribute to shaping and managing sustainable supply chains (Selviaridis and Wynstra, 2015).

5.4 Suggestion 4 – How the defence context influences learning and the development of PBL contracting capabilities

Both research and practice indicate that there is no single PBL contract that can fit all contexts. Even though this idea has been challenged by Glas and Kleemann (2017), we have shown that

the defence setting is rather unique (as compared to other sectors where PBCs are applicable) owing to its distinctive characteristics, for example the 'war *vs.* peace' binary environment within which defence buyers and suppliers operate. Prior research has largely downplayed this unique characteristic of the defence context. Accordingly, future research could, for example, explore the process through which PBL prime contractors, buyers, and sub-suppliers learn to contract when there is a transition from peace to war periods, and *vice versa*. Learning from previous defence contracts can help explain why, when, and how PBL becomes effective. Selviaridis and Spring (2018) studied how learning from previous performance-based contracts enables buyers and suppliers along the supply chain to align their performance goals and incentives, finding that learning improves buyer-supplier relationships. This means that, over time, PBL buyers and suppliers may be able to change their contract design and management practices in order to improve PBL effectiveness. Conversely, process research on PBL could also help to explain why and when defence departments might choose to transition away from PBL contracts, given recent evidence showing that the number of PBL contracts in the U.S. Department of Defence is decreasing (Sanders and Ellman, 2018). Based on the above, we propose:

Proposition 4: *The accumulation of learning about PBL contract design and implementation, both over time and across shifting operating conditions, increases the likelihood of improved PBL effectiveness.*

A longitudinal process view is needed in order to examine this further, enabling PBL effectiveness to be examined over time and as the context changes from peace to war. This is in contrast to the static view of PBL design and implementation that has dominated the extant literature (e.g. Sols et al., 2007; Datta and Roy, 2011). Such research would involve studying the evolution of contracts over time and the role of learning – to better understand how a defence buyer and/or supplier learns from extreme defence situations and subsequently adapts contractual incentives or performance targets. We suggest conducting qualitative research to explore how these situations affect the supply chain and how suppliers are able to respond. The dynamic capabilities literature may offer one potential theoretical basis for exploring the effect of the defence context on learning to contract.

6. Conclusions

This literature review has shown that PBL effectiveness is assessed in terms of cost, availability, reliability and maintenance effectiveness. Although, at first sight, these four performance measures are applicable to other industry contexts, they include some defence-specific characteristics (e.g. military mission reliability and logistics footprint) that sets them apart from generic effectiveness metrics. Further, we found that PBL effectiveness in the defence industry is influenced by a multitude of factors. We ultimately grouped 15 factors into six categories: governance of the buyer-supplier relationship, supply chain management, defence buyer input, innovation, environmental factors, and resources and capabilities.

Compared to prior literature reviews broadly on PBC, which span across disciplinary and industry sectors (e.g. Hypko et al., 2010; Selviaridis and Wynstra, 2015), we focused specifically on the defence industry and investigated the factors influencing PBL effectiveness in this one particular context. We leveraged four unique characteristics of the defence context to uncover distinctive factors (e.g. operational, political, regulatory, and cultural factors) that offered novel insights regarding service contracting in supply chains. Our findings have shown how such factors influence PBL effectiveness and provide a basis for future research, for instance regarding the influence of (geo)politics on defence procurement and contracting.

In addition, our research makes two key contributions to PBL research. First, we have synthesised and built upon prior literature on PBL design and implementation (e.g. Randall et al., 2011; Sols et al., 2007) to develop a classification framework on the factors influencing PBL effectiveness. Specifically, the framework offers insights into the relationships between 15 factors and their influence on four specific performance metrics used to evaluate PBL contracts. Second, we have augmented this framework by providing specific suggestions for impactful future research supported by a series of research propositions. This includes proposing that environmental sustainability and resilience requirements must be included when evaluating the effectiveness of PBL contracts and defence contracting more generally.

A key limitation of our literature review is that we have included peer-reviewed journal articles only, thereby omitting conference proceedings, books, and government reports. Although our sample could be supplemented in the future by other data sources, we strongly believe that our study is comprehensive in terms of covering all relevant research themes. In addition, we have focused on identifying factors that influence PBL effectiveness, but we have not explored any potential interrelationships between these factors. For example, relational governance is likely to be related to organisational culture, while contractual governance may

be associated with regulatory requirements. Future research could therefore build on our findings to examine the interrelationships between factors influencing PBL effectiveness.

Notwithstanding these limitations, our study offers novel insights regarding the effectiveness of PBL contracts in the defence context. Finally, we hope that we will inspire OSM scholars to further investigate the relevance of some of the factors we have uncovered to other industry contexts or PBC application areas.

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Appendices

Appendix A: Journals where the retrieved papers were published

	Journal	Frequency
1.	International Journal of Operations & Production Management	3
2.	International Journal of Production Economics	3
3.	Engineering Management Journal	3
4.	Journal of Public Procurement	3
5.	Systems Engineering	3
6.	Industrial Marketing Management	3
7.	Journal of Business Logistics	2
8.	Production Planning & Control	2
9.	Management Science	2
10.	Defence Acquisition Research Journal	2
11.	Military Operations Research Journal	1
12.	Journal of Business Research	1
13.	Journal of Service Management	1
14.	Journal of Purchasing & Supply Management	1
15.	Journal of the Operational Research Society	1
16.	Journal of Manufacturing Technology Management	1
17.	Journal of Reliability and Statistical Studies	1
18.	Journal of Defence Analytics and Logistics	1
19.	The International Journal of Logistics Management	1
20.	International Journal of Physical Distribution & Logistics Management	1
21.	International Journal of Production Research	1
22.	International Journal of Productivity and Performance Management	1
23.	International Journal of Defence Acquisition Management	1
24.	European Management Journal	1
25.	European Journal of Operational Research	1
26.	Service Science	1
27.	Sustainability	1
28.	Transportation Journal	1
29.	Quality Technology & Quantitative Management	1

Appendix B: Initial coding classification schemes

Classification Scheme	Category
Research Method	Open-ended category: inductively derived by reading the paper
Theory	Agency Theory
	TCE
	S-D Logic
	Other
	N/A
PBL performance Metrics	Cost of use
	Availability
	Reliability
	Maintenance effectiveness
	Other
Factors influencing PBL effectiveness	Supply and demand visibility
	Number of available suppliers
	Co-production
	Contract design
	Contract Management
	Relational governance
	Technology investment
	Maintenance improvement investment
	Product redesign
	Culture
	Politics and Regulation
	Other

Appendix C: Identifying relationships between influencing factors and performance metrics

		Cost	Availability	Reliability	Maintenance effectiveness
Governance	Contractual governance				
	Relational governance				
Supply-chain management	Supply-chain integration				
	Supply-and-demand management				
	Limited number of available suppliers				
Buyer input					
Innovation	Maintenance process innovation				
	Technology investment				
	Product redesign				
Environment	High-risk environment				
	Culture				
	Regulation				
	Politics				
Capability and resources	Learning and knowledge management				
	Human resources				

Appendix D: Report on the overall state of the PBL literature

With regards to methods (see Figure D1), case studies are the most common approach used in the literature, followed by modelling, grounded approaches and purely conceptual studies. Our interpretation of the popularity of case-based research in this area is that PBL is fraught with design and implementation challenges (e.g. Data, 2020), which may have encouraged researchers to study specific situations in depth in order to better understand the drivers and enablers of, and barriers to, PBL implementation. Case-study research also enables learning from successful implementations (Sols et al., 2012). Modelling is useful, especially for decision support-oriented research (e.g. the optimisation of inventory levels of spare parts (Mirzahosseinian and Piplani, 2011)); it is also attractive given the field access challenges in defence settings. We found only one study using a mixed-methods approach (Ng et al., 2013): The authors used qualitative data through interviews and observations to develop hypotheses which they then tested using a survey.

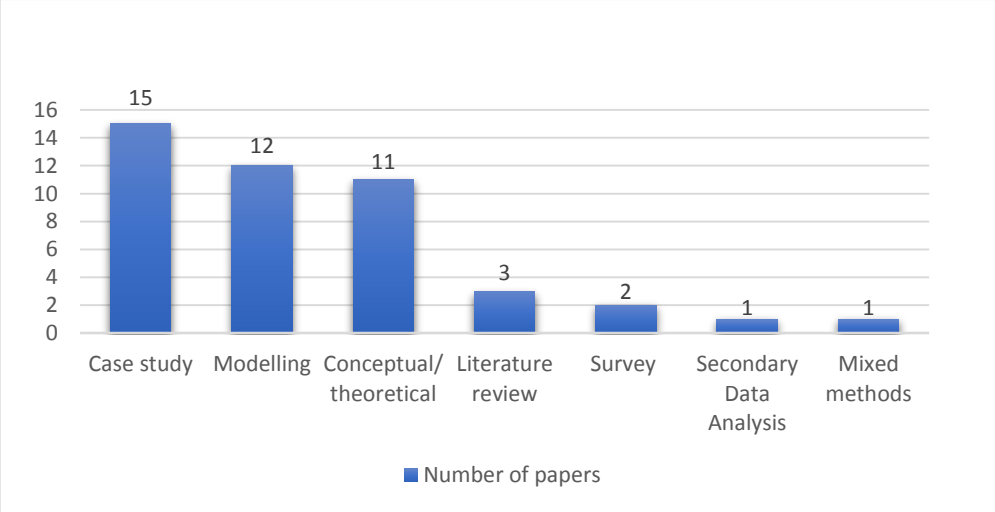

Figure D1: Research methods applied in 45 papers.

With regard to theoretical perspectives, we found that agency theory and service-dominant logic (SDL) are the two most commonly employed theories in the literature, followed by transaction-cost economics (TCE) and systems theory. Furthermore, it is noteworthy that the PBL literature includes many papers that do not employ any theory at all. This is especially true for papers published in engineering and military journals. Additional theories (e.g. resource-based theory, modularity theory, contingency theory, remote technology theory, theory of incentives, information economic theory, queuing theory and team research theory)

have been used, but rather infrequently. Figure D2 illustrates the key theories used, where some papers have used more than one theoretical lens and therefore contribute to more than one bar, while others do not use any theory at all and are therefore labelled as “N/A”.

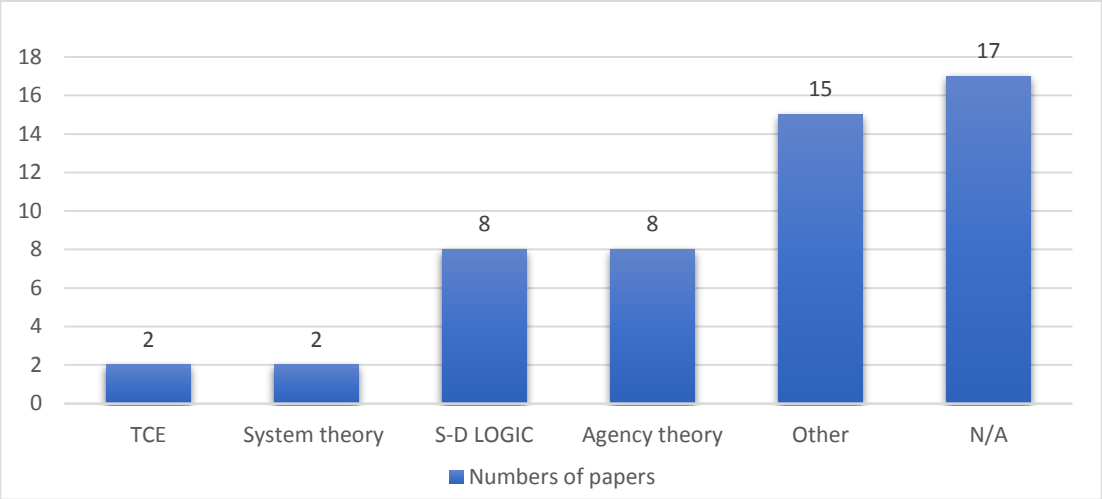

Figure D2: Theoretical lenses employed in the literature

Declaration of interests

☒ The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

☐ The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

CRediT Author Statement

In line with the Journal requirements, you will find below the authors' contribution.

Authors' contribution:

Faris Alqahtani: Conceptualization, Methodology, Validation, Formal analysis, Investigation, Data Curation, Writing - Original Draft, Writing - Review and Editing and Visualization.

Kostas Selviaridis: Conceptualization, Validation, Formal Analysis, Investigation, Writing - Review and Editing, and Supervision.

Mark Stevenson: Conceptualization, Validation, Writing - Review and Editing, and Supervision.

Thanks, and Regards

Faris Alqahtani

Corresponding Author

Approved by

Professor. Kostas Selviaridis

Professor. Mark Stevenson

Declaration of interests

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