

Peer reviewed article

Case Studies of Performance Based Logistics in the Military: International Lessons Learned

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Abstract

Performance-based logistics (PBL) represents a support strategy for weapon systems and manifests in contracts that focus on the delivery of outcome performance not process outputs. Despite the high research interest in the underlying theory, only few studies address the question how PBL is actually used. Some quantitative studies have researched this question by evaluating the perceptions of involved management people. Other data, such as prices, contract terms, or performance indicators, are often only available in form of qualitative case studies. Therefore, the purpose of this research is to report on a number of PBL cases and to provide a holistic view on their characteristics and the effectiveness as a support strategy. The analysis identified a high number of more than 100 cases that are reported in the literature. Filter methods are used to identify heterogenous case examples. The chosen cases are described and analyzed considering contract terms, price mechanisms and performance indicators. The findings show the wide range of PBL applications in international weapon system support. This guides this research to a number of research and practical propositions.

Keywords: Performance-Based Logistics; Weapon System Support; Case Study; Lessons Learned

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1. INTRODUCTION

Already in 2001 the Department of Defense of the United States of America (US-DoD) described performance-based logistics as the "preferred approach to product support" (US-DoD, 2001, p. 4). Since then, PBL has been used to increase availability and reliably of weapon systems while sustainment costs were stabilized or even reduced (Lucyshyn and Rigilano, 2019). A couple of studies already evaluated the effectiveness of PBL and provide empirical evidence on the positive effects of PBL, when properly implemented (e.g. Gansler and Lucyshyn, 2006; Guajardo et al., 2012; Boyce and Banghart, 2012; Lucyshyn et al., 2016).

PBL changes the traditional "pay for parts and services" approach of weapon system support towards a contract that is linked to expected performance outcomes (Mooney and Sanders, 2018). The details of the PBL approach are reviewed below, but what is of interest here is that PBL is not only a topic for the US-DoD. Since its emergence, the concept is used and implemented by a number of other countries. In particular, the United Kingdom or Australia are mentioned with specific incentive strategies that support PBL effectiveness (Mooney and Sanders, 2018). Case examples are reported from Germany (Kleemann et al., 2013), India bought Rafale fighter jets from France with PBL support (Walia, 2019), and the concept is also discussed in the context of Nordic countries (Listou et al., 2019).

The first passages of this article refer to the effectiveness of PBL and its applicability to various contexts. This reasoning is generally positive. However, some PBL pitfalls exist. First, PBL in the US-DoD is backed and encouraged for many years, but PBL contracting in the USA is still relatively rare and PBL contract numbers appear to decline since its peak in 2005 (Lucyshyn and Rigilano, 2019; Mooney and Sanders, 2018). This could be a warning signal that despite empirical evidence of PBL effectiveness, the concept might be outdated or at least the "hype around PBL" has reached a peak. The question is, if this is due to a lack of effectiveness.

Second, studies revealed that PBL is implemented in quite different ways (Glas et al., 2013). Thus, there is not only "one" PBL, but several configuration alternatives. For example, US DoD uses financial incentives in form of financial rewards or penalties, but also uses PBL in form of fixed-price contracts and surprisingly even cost-plus or pain-gain-share agreements (Hunter et al., 2018). Besides financial incentives, also time-based incentives are applied, because for a supplier the continuation of a business relationships is a main issue. This incentive is found to be a primary PBL incentive in some countries, e.g. Australia (Hunter et al., 2018). Overall, the diversity of PBL configuration alternatives might confuse and provokes the question which configuration fits best to a specific weapon system.

Both aspects guide this article to investigate how PBL is actually used. As already mentioned, some studies have researched this question (e.g. Lucyshyn and Rigilano, 2019). Often studies focus on the perceptions of involved management people (e.g. Glas and Kleemann, 2017; Gelderman et al., 2017). In addition, contract data of defense projects, such as prices, contract terms, incentives or performance indicators, are hardly available. This is why this article focuses on reported qualitative case studies. Therefore, the purpose of this research is to report on a number of PBL cases and to provide a holistic view on their characteristics

and the effectiveness as a support strategy. By applying this method, this research investigates the following research questions in accordance with case study research approaches (Yin, 2014). The first research question is addressing the effectiveness of PBL incentives, while the second question is focusing on time dynamics of PBL development.

> RQ1: Why incentives lead to an increase in effectiveness in the PBL case?
> RQ2: Why usage of PBL may have stalled and how will its application develop in the future?

Effectiveness is a measure for how well a goal is achieved. PBL usually aims at achieving performance goals which are operationalized with indicators such as availability, reliability, robustness, lead time etc. (Glas et al., 2018). This work is focusing on effectiveness, not on efficiency. Efficiency is measure for how much effort is required to achieve a goal. Already by its name PBL is performance-oriented. Thus, it is plausible to examine PBL from an effectiveness perspective. If effectiveness is not achieved, any other discussion about efficiency would be obsolete.

The remainder of the paper is organized as follows: We first give insights into PBL and its main characteristics in section 2. Next, the applied methodology of case study research is explained in section 3. This is followed by the case insights in section 4. Section 5 combines the insights to a meta-perspective. This is also the basis for the discussion and implications section 6. Finally, we provide conclusions and give details on limitations in section 7.

2. PERFORMANCE BASED LOGISTICS IN WEAPON SYSTEM SUPPORT

In weapon systems support, PBL is often sold as a completely new approach. However, roots of the approach can be traced back to the 1960s (Glas et al., 2013). Research is addressing the phenomenon, but the discussion uses several terms to describe it: "performance contracting"; "outcome-based contracting"; "performance-based logistics"; "performance-based payment"; "availability-contracting"; "incentive contracting" etc. (Selviaridis, 2011; Glas et al., 2013).

The essence of PBL stands for "outcomes are acquired through performance-based arrangements that deliver [weapon system] requirements and incentivize product support providers to reduce costs through innovation" (Defense Acquisition University, 2016, p. 6). The outcome is usually defined in form of metrics (e.g. availability, reliability, operability). In PBL we see a separation between the performance expectations (outcome goal), and the supplier´s way of implementation and how this goals is achieved (Kim et al., 2007). Thus, supplier efforts must focus on the achievement of the given goals. "The key to a successful PBL arrangement is the use of incentives to elicit desired behaviors and outcomes from the [supplier…]" (Defense Acquisition University, 2016, p. 11).

Every contract is providing a specific form of incentive to a supplier. Recent research, following Hunter (2018), has shown that in PBL financial incentives, but also time-based, scope-based or relational/other incentives are feasible. Thus, PBL includes monetary reward or penalty systems (bonus/malus payments), but also

incentives that are related to the extension of a contract duration or the extension of the contract size and scope. This research work is fully aware that incentives in a contract are a complex topic. The insights into the cases will show that time-based incentives (e.g. options for additional contract duration) are used together with financial incentives. However, this article focuses on financial incentives and tries to evaluate how these incentives effect supplier behavior.

Supplier behavior then leads to contract outcomes. The contract outcomes in PBL are often not only influenced by the supplier. Other influencing factors are simply how often, how intense and under which conditions weapon systems are used. Nevertheless, outcomes are measured via performance indicators that are related to requirements in the contract. These metrics are availability, reliability, operability and Glas et al. (2018, table II and III) provide overviews with already used key performance indicators. Management control is also an (relational) incentive.

However, it is assumed that financial incentives which are linked to performance metrics are the main source for motivation effects on supplier behavior. It is stated that the most challenging element of a PBL is the pricing model (University of Tennessee and Supply Chain Visions, 2012). This is why the focus in this article is on financial incentives.

3. METHODOLOGY OF CASE ANALYSIS

3.1 Brief insights into case study research

This research applies case study research as the major methodology. A case study is defined as an "empirical inquiry that investigates a contemporary phenomenon (the "case") in depth and within its real-world context, especially when the boundaries between phenomenon and context may not be clearly evident" (Yin, 2014, p. 16.). Thus, it is the aim to better understand the phenomenon in its context.

This suits very well to the topic of PBL, which is a phenomenon often discussed as a single concept or strategy, but in fact it has a diversity of configurational alternatives. Furthermore, weapon systems and weapon system support systems differ from country to country. Therefore the exploration of PBL through case study research is justified.

Often case study research is examining a single case. However multiple-case design have increased in frequency in recent years and according to Yin (2014) multiple-case designs have specific advantages in comparison to single case studies and in comparison to quantitative survey. First, the evidence derived from multiple cases is perceived more robust and external validity is enhanced. Second, multiple cases allow to cross-evaluate and combine findings. In contrast to multiple respondents in a survey, insights from multiple cases is not testing a cause-effect, but allows to examine a cause-effect in-depth in different contexts. The examination of a phenomenon in multiple cases is also called replication design.

This suits very well to the aims of this research. PBL is an innovation as it provides new approaches to weapon system support. Countries /armed forces adopt PBL for individual weapons systems in a specific manner and in a specific configuration setting. Therefore, each PBL can be subject of an individual case study, but the study as a whole covers several PBL and thus uses a multiple case design (see also Yin, 2014, p. 56).

3.2 PBL case population: An initial quantitative view

Before examining cases in order to address the research questions, this section focuses on the overall population of PBL cases, of which data is available. PBL has its routes in the USA, so we have a strong look on the situation in the USDoD. PBL is described as the preferered product support strategy, but surprisingly "PBL is not being aggressively pursued" (Lucyshyn and Rigilano, 2019, p. 345). The number of PBL has decreased since its peak in 2005 of around 200 PBLs in place to around half the number of 87 PBLs in 2012 (Erwin, 2013). This means that "only 5 percent of the (US) military´s maintenance work is performed under such deals" (Erwin, 2013). Figure 1 shows that PBL contract obligations of the USDoD gradually declined after its peak in 2013 (data extracted from Hunter et al., 2017).

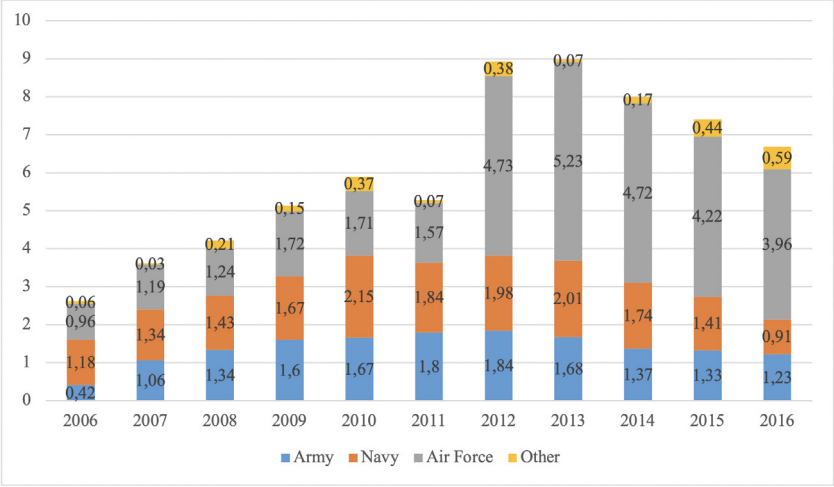

Figure 1: PBL contract obligations in billion US-$ (constant 2016), Data from Hunter et al. (2017)

Besides the PBL in the USDoD, the author of this article has identified in his research another 100 PBL contracts. The collection of cases was an initial step of this research approach. Of these cases, some are from the public sector (e.g. police equipment, rail maintenance, infrastructure), but there are also PBL for weapon systems in other countries. The cases have been identified through publications in academic journals (e.g. Priva Datta, 2011 with two cases on aircraft spares or Kleemann and Eßig, 2013 with five cases). However, most cases are only presented with vague or very limited data. This prohibits a quantitative cross-case analysis with all cases.

However, both figures (87 reported contracts of the USDoD and 100 identified international cases from the literature) point to the same issue: In face of hundreds or thousands of other contracts (it is mentioned above that PBL in the USA has a share of 5%), PBL seems to be a niche approach, as the number of contracts is relatively low. This fits to the argument that each PBL is unique and PBL is customized because "one size does not fit all" (Geary and Vitasek, 2008; Glas et al., 2013).

The configuration of PBL depends on how incentives are understood (Mooney and Sanders, 2018). Some voices acknowledge that every contract provides a specific incentive structure, but propose to focus the PBL discussion on contracts that use a bonus/malus payment scheme (Glas et al., 2013). Other voices describe PBL as an approach that can use the whole range of price mechanisms: Cost plus, (firm) fixed price, and incentive price scheme (Lucyshyn and Rigilano, 2019, p. 350). Through the incentive mechanism, a PBL supplier is getting a specific profit opportunity and takes over a specific amount of contract risk. Therefore, the understanding of incentives is crucial for PBL. Data on the use of incentive schemes show that the majority of PBL in USDoD are firm fixed price (68% of all contracts, Hunter et al., 2017). Besides the payments scheme, there are also time-based or relational incentives available to configure PBL. Contract continuation and more intense cooperation are to mention here. However, those incentives are often not strong, because the level of competition for PBL contracts is low. Hunter et al. (2017) showed that 78 percent of USDoD PBL contract obligations have been awarded without competition. In a single source situation contract continuation for weapon system support is not a strong incentive, because the supplier is more or less set. Competitors are often not entering the market, because they would need to establish a new supply chain. Therefore, the core configuration variable of a PBL is the price incentive mechanism and this research will show how this is executed in the cases. Obviously, suppliers in a non-competitive market are risk averse, thus reluctant to PBL. Defense acquisition officials are also risk averse. Thus the implementation of the incentive structure is a key challenge than needs to be overcome as a good PBL should be in the interest of both parties.

The initial quantitative view on PBL cases reveals that PBL is seemingly a niche strategy for weapon system support, while on the other hand there is a range of configurational alternatives to form PBL. The major variable is the price incentive mechanism. Both aspects (*niche strategy* and *PBL diversity*) might explain, why the literature is still fragmented and most research addresses the topic with abstract mathematical modeling or in-depth single case study methodologies (Selviaridis and Wynstra, 2015).

3.3 PBL case selection

Following the multi-case study research design, it is the purpose to select cases that have the same phenomenon, of course, but differ in their context and content. Yin (2014, p. 58) recommends to select around 4 cases or more to investigate contrasting insights for assumed cause-effects. The guiding two research questions aim clearly to explore different and contrasting reasons, why incentives increase effectiveness of weapon system support and why PBL implementation has stalled.

To get valid and objective answers, the selection of cases in multiple-case study research designs is quite similar to how an experiment is designed. In a series of an experiment several observations are taken with a dependent variable that is influenced by independent variables. In an experiment some observations are taken without and some with a change in the independent variables (stimulus). If the dependent variable changing, then the experiment has shown the cause-effect form the stimulus to the dependent variable. Similarly, case selection in multiple

case study designs aims to identify cases that have clearly different contexts and case contents. Then, it might be possible to identify reasons why results in the cases differ, because the differentiating factors are known.

The following figure 2 illustrates the chosen cases. It is depicted that case background is located either in the USA or in Germany. Besides, the level of application differs and ranges from parts/components to the system level. In addition, the case context differ, because object of analysis (recipient of PBL service) is also heterogenous and ranges from single to multiple aircraft fleets and also includes a land-based rocket launcher system. Furthermore, the case content also differs. Contract duration and incentive structures as well as fleet size and other characteristics differ. The characteristics of each case are presented in more detail in the analysis section.

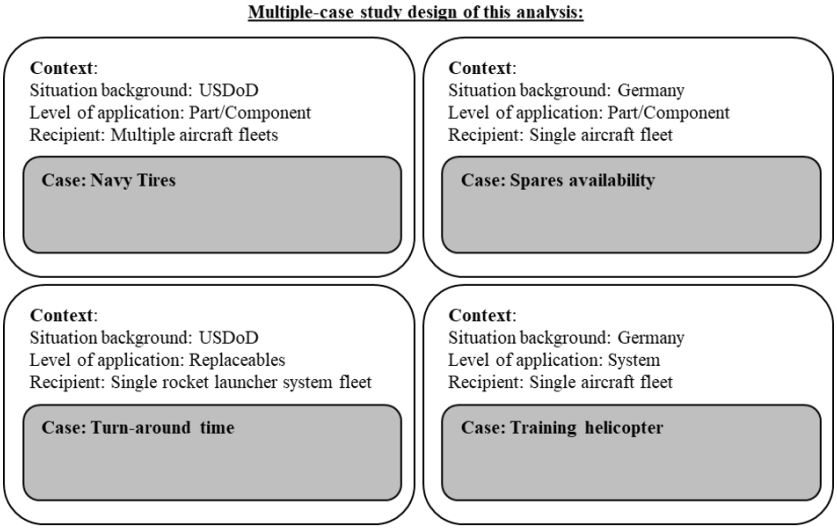

Figure 2: Cases and contexts analyzed in this research.

3.4 PBL case data

Data for the case analysis has been collected by means of literature analysis. For each case at least one major source of information has been identified. The data presented in the source is enriched with other data from academic literature on the same case. General data of the weapon system and on its usage life-cycle are also added from other publications. Overall, this research did not collect primary data on the cases, e.g. through interviews, observations or other empirical methods. Data gathering is following the analysis of secondary data.

Secondary data is the analysis of data that was collected by someone else for another purpose (Johnston, 2014). The use of existing data provides several opportunities for researchers, e.g. saving of time and resources but also simply getting access to a specific phenomenon. This is relevant here, because research

in defense economics is generally challenged by confidentiality requirements and limited data access. However, analyzed secondary data had initially another focus. Therefore, "secondary analysis of data requires a systematic process that acknowledges challenges of utilizing existing data" (Johnston, 2014, p. 625).

This research generally follows the generic procedure according to Johnston (2014): (1) Develop the research questions, (2) Identifying the dataset, (3) Evaluating the dataset and assessing the quality with regards to consistency, reliability, validity, objectivity.

4. CASE PRESENTATION AND ANALYSIS

4.1 Case 1: Navy Aircraft Tires

This case refers to Navy aircraft tires. The major source of information of this case is the report of Lucyshyn and Rigliano (2019). The case context has been enriched with other publicly available sources.

Traditionally, aircraft tires have been bought in bulk on basis of contracts for individual types of tires. Then, the tires were stored until they were needed, what resulted in large inventory stocks. On the other hand, specific tires still were scarce and stock-out was a severe risk. Tire availability was 81% before entering into the PBL, what was perceived as a severe bottleneck.

The Navy developed and implemented a PBL on component level. It started with an initial firm-fixed price contract starting in April 2001 and now lasts on until today. Contract duration was five-years with two five-years options. The first supplier, Michelin Aircraft Tires Corporation, was responsible to supply all types of aircraft tires that the Navy used. The contract had two extensions in 2005 and in 2010, so the PBL contract ended in 2016 after 15 years. The follow-up contract was competitively awarded to another supplier, Lockheed Martin. It was also a firm-fixed price contract and contract duration of three years with two options of six months each. Contract values have been $67.4 million (1st phase), $92 million (2nd phase), $101 million (3rd phase), and $131.3 million (4th phase with new supplier).

The contract requirements were to achieve a 95% on-time fill rate within 48 hours in the US and within 96 hours outside the US, while also other objectives are mentioned, e.g. reduction of inventories, demand flexibility of up to twice the monthly demand rate, if required.

The source provides data, that the contract was effective, because all requisitions were filled. In 2011 over 289,000 tires have been delivered worldwide and the supplier Michelin Aircraft Tires Corporation managed to consistently exceed the on-time delivery metric with a level of around 98.5%. Customer wait time was 32.1 hours within the US and 59.5 hours outside the US. Also Lockheed Martin managed to exceed the on-time delivery metric consistently with 98.2% within the US and 98.7% outside the US.

To achieve the set contract requirements, suppliers established specific management and execution structures, e.g. data exchange was established that allowed real-time demand status monitoring. Also, a service center that is available 24/7 was established. Besides, a monitoring system was established that provided insights into delivery times, inventory accuracy, and order fill time as well as transport carrier performance.

These are indications that the supplier is incentivized through the firm-fixed price to invest in reliability improvements, thereby reducing future costs. But the incentive is framed by the contract duration. "Generally, PBL contracts of shorter duration will not incentivize significant contractor investment since the contract must be long enough for the contractors to recoup their investments" (Lucyshyn and Rigliano, 2019, p. 368).

4.2 Case 2: Spares availability

The next case refers to the weapon system EUROFIGHTER and a specific support contract. The major source of information for this case is a joint position paper of the German aerospace industry association (abbreviated BDLI) and the German Bundeswehr (BLDI, 2018). However, presented data to the case is limited in that source. Besides, additional information to the case context is given by several reports of the German-Ministry of Defense (D-MoD), e.g. D-MoD (2019 and 2020).

Traditionally, the responsibility for all tasks related to the supply of the weapon system with parts and components was on the side of the German Bundeswehr. These tasks included the management of parts and components, procurement, storage, transport, and the planning and monitoring of the cycle of replacement parts. Other countries that use the weapon system have specific support contracts in place, which focus on availability. In particular, the United Kingdom awarded in 2009 a "contracting for availability" PBL support for their fleet to BAE systems (BAE Systems, 2020). That support in the UK also comprises logistics services such as the monitoring and management of all day-to-day operations to deliver spares and repair services (BAE Systems, 2012). The German Bundeswehr was confronted with challenges in the supply of the weapon system. Official publications mention "problems in the operational readiness" (D-MoD, 2015) and public media frankly talk about lacking spare parts (Gebauer, 2015). Thus, the Bundeswehr implemented a PBL contract to address this problem.

The contract (Eurofighter Vertrag C#3) has a duration of five years, but the source from 2018 mentions that the PBL just has been started. The contract situation is still in the transition phase. The supplier is taking over all supply chain management task (transport, storage, repair and overhaul of replacement parts). The contract requirements were to meet a material availability KPI, which is measured in response time frames of one hour, one day and 30 days. Within the 30-days timeframe, the objective is set to achieve a material availability of 99%. Similar to the above mentioned approach in United Kingdom, the contractor is also providing services on air force bases with own personnel. The main source of information is not providing any indications how the payment and incentive scheme is implemented in the case. But there are some general remarks on PBL in that paper: "It is ideal solution for PBL to link outcome-oriented KPIs with economic incentives" (BDLI, 2018, p. 7). Following the classification that the EUROFIGHTER-PBL is seen as PBL in the narrower sense, it is assumed that there is a reward scheme implemented in the case (bonus linked to material availability).

Overall, the case shows positive effects of PBL. In an official report, the Bundeswehr states that PBL in the EUROFIGHTER case has significantly in-

creased the availability of ready for operation aircrafts (D-MoD, 2020, p. 9). More specifically, that report mentions that the EUROFIGHTER fleet saw an increase in the fleet availability ratio of +60% (D-MoD, 2020, p. 4).

4.3 Case 3: Turn-around-time

This case refers to a rocket launcher weapon system called HIMARS (High-mobility Artillery Rocket System). The major source of information for describing the case is the report of Lucyshyn and Rigliano (2019).

HIMARS entered prototype production in 1999 and series production in 2003. The system is referred to as the most advanced artillery system in the U.S. arsenal. It is a wheeled and thus very mobile rocket launcher on basis of an armored truck. Already in 2004, when the first HIMARS launchers entered into service, a first PBL contract has been awarded by the Army to Lockheed Martin (around 195 launchers), while HIMARS at the Marine Corps (around 40 launchers) was supplied outside that contract. The objective of the PBL was to optimize or reduce costs while having flexibility in operational requirements. Compared to the weapon system support for the preceding system M270 MLRS, inventory management, reserve stock, repair and overhaup, depot maintenance etc., was not executed by the military, but by the PBL supplier.

The first HIMARS contract had a duration of three years (one base year and three option years). The volume was $96 million. In a second contract, Army and Marines systems were supported. That contract lasted for three years (one base year with two option years) and had a volume of $90 million. A third contract extended the PBL support until 2014 and had a volume of 158 million. Then, USDoD decided to transition weapon system support for HIMARS to a traditional cost-plus contract. This transition is of peculiar interest.

The supplier took over the full support responsibility. This included on the one hand side even the optimization of HIMARS usage. Data analysis revealed already in the first contract, that HIMARS launchers are used very different. Categorization in less used systems with low operational support tempo, and more used systems with high operational support tempo helped to reduce costs. On the other hand, the supplier efforts also referred to personnel embedded at military sits (called field service representatives). That personnel had a number of tasks, but a major advantage was to repair HIMARS very quick. Branded "Fix Forward", field representatives repaired around 50% of all HIMARS on-site. In addition, logistics costs were saved, because field representatives were trained to open replacement components. So only parts or components need to be shipped instead of the whole replacement component.

The PBL was a firm-fixed price contract with performance incentives for state-side operations. If performance requirements were met, an additional fee was paid to the contractor. For overseas operations a cost-plus fixed fee contract was used.

The PBL contract contained three metrics: system readiness, response time for part delivery, and repair turnaround time. System readiness objective was 92% in the first contract, and 90% in the second one. This metric was not include in the third contract. Delivery time was measured in percent of delivered parts within a timeframe and priority group. For example, demands in in priority group 1 had to

be fulfilled within 48 hours within USA and 96 hours outside USA in more than 92% of cases (see Lucyshyn and Rigliano, 2019 for more details).

The third metric is of peculiar interest here. It is turnaround time and specified the time period for completing repairs for replacement parts. The requirement was set in working days (see table 1). In other words, 65% of all replacement parts have a turnaround time less than 36 days, and 92% of all replacement parts a turnaround time less than 80 days.

Table 1: Metric calculation in the rocket launcher case (data from Lucyshyn and Rigliano, 2019).

Band	Repair turnaround time	Requirement (percentage of total repairs)
1	1-7 days	≥18%
2	8-35 days	≥47%
3	36-80 days	≤27%
4	81-90 days	≤8%
5	91 days	1%

Overall, it seems as if the PBL was successful. System readiness was 99%. Spare parts delivery time was 14 hours within the USA and thus far below the requirement of 48 hours. Turnaround time in the field (by the field representative) took 1.2 days, only. Repairs at the site of the supplier took on average 34 days. The source of information also reports on calculations which measured total cost avoidance – only due to improved planning of operational tempo. Cost avoidance was $8.6 million. Therefore, the contract seemed to be a success.

The major source of information further explains how and why the contract was changed towards cost-plus. This is also of peculiar interest for RQ2. It is mentioned that USDoD aimed to have more control. Direct control over stocks by the government and given stock objectives should help to achieve this. However, the source also provides some indication that supplier lost flexibility by this new arrangement (no optimized order quantities with sub-suppliers, no incentive to further invest into the program). Nevertheless, the source also acknowledges that performance under the cost plus agreement is still good. All metric requirements are (still) on a high level.

4.4 Case 4: Training helicopter

This case refers to the training helicopter system EC135 of the Bundeswehr and its support contract with the industry. The major source of information originates in a reader book on PBL from 2014 (Eßig and Glas, 2014) with specific chapters that describe the case (Haindl and Hänger, 2014; Muntz, 2014). Similar to case 2, additional information is added from reports of the German Ministry of Defense.

The helicopter fleet of 14 EC135 is located at one training center location. The helicopter is not for combat training but basic training, thus EC135 is also a commercial helicopter with around 1,000 systems sold in the world. The problem in this case was, that the budget for the operation of aircraft fleets in the Bundeswehr is of course limited. Even if the budget increases over time, it often does not keep pace with the general cost increase (Muntz, 2014, p. 170). A solution to the problem for the Bundeswehr was to concentrate on core tasks and efficiently execute non-core tasks. Training helicopters such as the EC135 are not within the core tasks, this is why Bundeswehr searched for a solution to economize costs while at the same time have the helicopters available in a very flexible manner.

The solution was a PBL contract in which the industry, namely Eurocopter (today Airbus helicopters), takes over the whole responsibility for the helicopter fleet. This included spare supply management, maintenance, repair and overhaul, tooling, inspections, documentation and other tasks. Only fuel-filling and usage (flying) are tasks that are performed by military personnel. All support processes are at the supplier side. The contract started in 2005 and had an initial duration of five years. In several extensions (five years, five years, seven years), the contract is now agreed until 2022. The contract payment scheme is "pay-per-unit", a fixed price per flight hour (BDLI, 2018).

Overall, performance of the training helicopter is positively mentioned in the sources. The long-term ratio of mission-ready aircraft provision is above 80% (D-MoD, 2020). In a specific analysis, the ratio goes up to 99.4%, when not executed missions due to bad weather conditions or illness of pilots are not regarded (Haindl and Hänger, 2014). But the main objective was also to economize fleet operation costs. Information on this issue are rare, but Haindl and Hänger (2014) mention, that costs are far below (-50%) compared to the costs for a flight hour of the previous training helicopter BO-105. Thus, also this case shows positive effects of PBL.

5. DISCUSSION AND IMPLICATIONS

5.1 Cross-case comparison

Before we discuss the findings, this section summarizes the cases and provides a meta-view. Overall, the case analysis shows four PBL examples, two from Germany, and two from the USA. Case selection focuses on two PBL examples on parts/components level and two examples on system level.

In every case, a severe initial bottleneck situation is mentioned and the PBL approach shall address this issue. For navy aircraft tires and the spares availability case, the bottleneck is the low availability of spares, while stocks are existent but often not with material that suits demand. A different bottleneck exists for the other two cases. There, new systems are introduced and PBL shall help to avoid or at least stabilize weapon system support costs on the one hand side. On the other hand, PBL shall provide an instrument to safeguard a high contract performance even in changing conditions. In both cases, flexibility is provided and incentivized.

The cases from the USA show long overall contract duration with many contracts or contract option. In case one, two contracts with three options are identified through the main source of information. In case three, we see three

contracts and the first two contracts with an additional option. This is an indication that time-based incentives are also used to motivate the supplier, not only financial incentives. The same can be seen in the German cases, however, single contract terms are not below 5 years.

Every PBL has an key performance indicator, which is operationalized in several aspects. Navy aircraft tires measures on-time-delivery in hours and differentiate the area (USA, non-USA). In the EUROFIGHTER case, material availability is differentiated in three timeframes (one-hour, one-day, 30-days). The cases with the rocket launcher is the only one in this sample that uses several KPIs (system readiness, response time for part delivery, and turn-around time).

The KPIs are linked to a specific contract type/price mechanism. The range is from firm-fixed price (navy aircraft tires) to pay-per-unit-price (training helicopter), while the other two cases add financial incentives to other price mechanisms. All regarded cases are perceived as effective and successful. Three PBL are ongoing. Only one contract has seen a transition away from PBL towards cost-plus (see Table 2).

Table 2. Overview on the four cases.

	Navy Aircraft Tires	Spares Availability	Turn-Around-Time	Training helicopter
Country	USA	Germany	USA	Germany
Level	Parts / Components	Parts / Components	System	System
Initial bottleneck situation	Low availability but high stocks	Problems in the readiness of the fleet (due to lack of parts)	Cost avoidance while need for flexibility	Cost avoidance while need for flexibility
Duration (years)	(5+5+5) + (3+0,5+0,5)	(5+5)	(1+3) + (1+2) + 3	5 + 5 + 7
Sum duration (years)	19 (ongoing)	10 (ongoing)	10 (transition to cost-plus)	17 (ongoing)
KPI	On-time-delivery	Material availability	Turn-around-time (besides system readiness and response time part delivery)	Mission-ready aircraft preparation
Price mechanism / contract type	Firm-fixed price	Financial inventive is used	Financial incentive is used	Fixed price per flight hour
PBL effectiveness	Yes	Yes	Yes	Yes

5.2 Implications referring to RQ1: PBL incentives and effectiveness

Referring to the first research question, why and how incentives lead to an increase in effectiveness, the findings from the PBL cases support previous observations in academic and practice literature on the topic. First of all, it is to state that all observed cases have been effective. This is not surprising. Typically, PBL are reported as successful. E.g. Defense Acquisition University (2016) reports on 21 analyzed PBL, of which 20 have been effective and the sole program without improvements is marked with a footnote that malperformance is not due to the PBL arrangement, but due to other causes. The US Governmental Accounting Office published several critical reports on PBL, but usually it criticized badly implemented PBL (without good business case analysis, GAO, 2008) or the criticism was too early. In 2005 a report of GAO mentions that only 1 out of 15 analyzed programs showed improvements.

As we see in our case of the navy aircraft tires, it took quite a while in the case to achieve the performance goals. But overall, sources from the US indicate that PBL is effective. In the same manner, the German MoD is arguing. Considering the political tenor of the report, the preliminary conclusion to PBL is very positive (D-MoD, 2020). It is stated that PBL is another possibility to increase the operational availability of weapon systems. Furthermore that report clearly points out that PBL was successful for all mentioned cases in that report (e.g. EUROFIGHTER, engine NH90 helicopter, EC135 training helicopter, LUH SOF helicopter). This provides a clear indication that PBL is not only effective in the USA but also in Germany.

Overall, it seems as if the use of incentives and management by outcome-objectives is key for PBL effectiveness. However, we see that it is not only a financial incentive that is of relevance. Only two cases use these bonus systems. The other cases use fixed prices and link them with the effectiveness ratio. Combined with time-based incentives (contract extensions), this is also a suitable approach to incentivize a supplier to improve its PBL services for the Armed Forces.

5.3 Implications referring to RQ2: The future of PBL

Referring to the second research question, why the usage of PBL may have stalled and how its application will develop in the future, we have two different observations. To answer this question, we also refer to the "hype" and "business maturity" – issues that are used to assess new technologies or new business concepts (Fenn and Roskino, 2009; Dedehayir et al., 2016).

In the USA, only few percent of the (US) military´s maintenance work is performed under PBL (Erwin, 2013). Recent studies indicate that PBL is required, because there is still demand for reliable technology. However, PBL is not being aggressively pursued throughout the USDoD (Lucyshyn and Rigliano, 2019). However, it is the "preferred approach to product support" (US-DoD, 2001, p. 4). Overall, it seems as if PBL was and still is a niche strategy for specific weapon system (support challenges).

Challenges for PBL come from two main directions: First, criticism in early PBL-days focused on a potentially higher risk of security of supply and reliability (Gansler et al., 2011), but this did not prove to be founded. PBL supported systems

even operated in very dynamic conditions and companies did not per refuse to further support them. "PBL-supported systems operating in stressful environments have met or exceeded performance requirements" (Lucyshyn and Rigliano, 2019, p. 346). Second, critics of PBL focus a bit more on the effectiveness and efficiency of that weapon support strategy. This is in line with the reasoning mentioned by Selviaridis and Wynstra (2015), who question if performance-based incentives in long-term contract relationships are sustainable over time, because supplier ability to learn and to use innovation for service improvements become more and more marginal. That logic is convincing, because often the initial situation is characterized by very severe bottlenecks. Thus, PBL can achieve high initial improvements. As PBL is applied in the USA for more than 15 years, now, the question is, if PBL must achieve continuous improvements or sustainable high performance. If the latter is possible, then PBL is not stalled but focuses in its application fields of challenging niches of weapons system support.

In Germany, PBL is of course a niche strategy. The German MoD reports on only four explicit PBL applications for weapon system support, out of 68 major weapon systems (D-MoD, 2020). Referring only to these figures, then 5.8% of all weapon system support contracts are PBL in Germany, but there might be a dark figure of unreported cases (at subsystem level or for systems not counted as major weapon system. However, the PBL niche strategy is gaining momentum in Germany as it is considered as a future solution for industrial weapon system support in the German military aerospace strategy (D-MoD, 2016). Considering the high variability of the availability ratio per weapon system (new systems between 30% and 93%), mature systems (60 to 100%) and old systems (26 to 89%) it seems as if there are still weapon systems with significant deficiencies in their availability, what could be a starting point for a PBL weapon system support approach. There are no indications that Germany already reached a "peak" or "stalled" PBL implementation. Contrary, more and more official documents refer to PBL and recent papers explicitly give top-level support. For example, the German Air Force strategy (D-MoD, 2016) states that PBL is ground-breaking and international PBL experiences are paving the path.

Coming back to "hype" and "business maturity", one could say that PBL in USA has still strong support, but the initial hype is over. On the other hand, PBL gained a higher level of business maturity. Methods and instruments to plan, arrange, execute, and monitor PBL are in place in the USA, e.g. PBL guidebook (Defense Acquisition University, 2016). This is why PBL is focusing on more specific fields of application, there. In Germany, it seems to be the other way round. PBL is gaining momentum, it is in a "hype". On the other hand, PBL in Germany profits from foreign experiences. Business maturity of German PBL is quite high and similar to other international examples. Overall, German "enthusiasts" and USA "realists" have different perceptions of PBL to solve generally weapon system support problems, but in the USA as well as in Germany PBL still gains business maturity relevance or popularity (Stanley-Lockman, 2020). The findings of this analysis imply that the relevance is for specific and notably challenging weapons system support situations.

6. CONCLUSIONS AND LIMITATIONS

This article reports on PBL, if and why it is effective and if PBL is also a concept for the future. The case examples show that PBL is implemented in a heterogeneous way, what is named as PBL concept diversity. Nevertheless, all cases are effective, even if PBL implementation is different from case to case. This is also a potentially interesting field for future research. Next, the analysis and discussion show that even after decades of PBL existence (in the USA), the concept still gains relevance for future applications. In Germany many systems still are not treated with PBL, so only specific systems have been addressed up to now. In the USA, availability problems of a range of systems have been addressed in the past, so the future of PBL could address in more focused and sharpened application for more challenging performance objectives.

However, this research is also facing a number of limitations. First, empirical basis is limited with only four cases and each case builds on main sources of information. Second, the observed PBL may represent sub-types. More cases would enable a more fine-grained analysis on incentives and their effectiveness. Third, most cases are from aircrafts and only one case is from a ground-based system. A navy case is missing. Fourth, most PBL are very long-term projects. Every evaluation of their effectiveness is biased by time dynamics. Overall, future research should further investigate and elaborate the main finding of this work: PBL is effective, but it is a niche strategy for which the concept has a future!

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