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Public–Private Partnerships in Defence Manufacturing: Performance, Risk Sharing and Accountability

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Abstract
World military expenditure reached US$2,718 billion in 2024, a real rise of 9.4% and the steepest annual increase since at least 1988, and governments now ask private manufacturers to expand defence output faster than state arsenals can. Public–private partnerships (PPPs) are the main contractual vehicle for this, yet the evidence on whether they deliver value, how they share risk, and who answers for failure is scattered across audit reports, policy documents and a thin academic literature. This review synthesises 101 sources published up to October 2026 on PPPs in defence manufacturing and support, drawn from the United Kingdom, the United States and India. It then develops a Performance–Risk–Accountability (PRA) framework that links a risk-adjusted value-for-money test, an optimal cost-sharing rule and an accountability condition for contestability. Four findings stand out. The UK National Audit Office could not conclude that the £10.5 billion, 27-year tanker PFI achieved value for money, and negotiations took over nine years. The UK government-owned, contractor-operated reform of defence procurement collapsed in 2013 with one bidder. India's private sector raised its share of defence production from 21% to 23% in FY2024-25, while only 14.5% of Rs 74,756 crore of corridor investment commitments had been grounded by April 2026. The framework implies that high-uncertainty development work should carry low private cost shares, mature serial production high shares, and that accountability fails when the state cannot credibly replace its partner.

Index Terms—Accountability, defence acquisition, defence industrial base, government-owned contractor-operated, India, private finance initiative, public–private partnership, risk allocation, strategic partnership, value for money.

I. Introduction

Defence budgets are growing faster than the industrial capacity that must absorb them. World military expenditure rose to US$2,718 billion in 2024, 37% higher than in 2015, and the global military burden reached 2.5% of GDP [1]. Arms and military-service revenues of the 100 largest producers rose 5.9% to a record US$679 billion in the same year [2]. India, the fifth-largest spender at US$86.1 billion [1], recorded defence production of Rs 1,50,590 crore in FY2024-25, 18% above FY2023-24 [3]. Exports reached Rs 23,622 crore, of which private firms supplied Rs 15,233 crore, or 64.5% [4].

The policy response in most of these states is to draw private capital, management and technology into defence manufacturing through long-term partnerships. The model rests on one assumption: that transferring defined risks to a private partner lowers the whole-life cost of a capability without weakening the state's control over it. UK experience shows why the assumption needs testing. By 2016-17 the UK had over 700 operational PFI and PF2 deals with a capital value of about £60 billion and annual charges of £10.3 billion, and the National Audit Office (NAO) found that there was still too little data to show whether private finance had delivered better value than conventional procurement [5].

The earlier literature can be classified as follows: - reviews of PPPs in general, which evaluate infrastructure contracts and yield conflicting results as to the success of such contracts [6],[7]. - economic modeling that determines situations where PPPs will lead to improved performance through increased incentives created by bundling and risk transferring [8]. - accountability studies that explore the holding of partnerships accountable to the public [9]. - a limited amount of defense related research has been conducted. They include studies of the UK MOD PFI program and

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whether it could be used in other countries [10]-[13] and an assessment of India's 2020 acquisition policy [14]. However none of the above research combines performance, risk sharing and accountability into one model, nor compares the models of UK, US and India on the same criteria. The present review will accomplish two tasks; it will answer the three research questions (RQs). RQ1: how have defense manufacturing PPPs performed against a reference standard? RQ2: Which risk allocations are used in defense manufacturing PPPs and how do they correspond with the predictions of contract theory? RQ3: What accountability mechanisms exist for defense manufacturing PPP partners and Ministries of Defense and their failures? Section II presents the methodology applied. In Section III the types of partnerships used in PPPs for defense manufacturing, and the legal framework under which they operate are discussed. Sections IV-VI address RQs 1-3. Section VII integrates the findings of RQs 1-3 into a Performance-Risk-Accountability (PRA) framework, and proposes potential topics for further research. Finally, in Section VIII some main findings are concluded.

II. Review Method

This is a narrative review structured rather than a meta-analysis. There are few defense PPP contracts, they are heterogeneous and partly classified so pooled effect sizes cannot be estimated. Instead, the review codes each source for the type of evidence it provides and compares cases on common criteria.

A. Sources. Five source families were searched up to October 2026: (i) supreme audit and legislative reports (UK NAO, UK Committee of Public Accounts, US Congressional Research Service); (ii) official policy and statistics (India's Ministry of Defence and Press Information Bureau, SIPRI); (iii) peer-reviewed PPP theory and evaluation in public administration, project management and economics journals; (iv) defence-specific monographs and theses; and (v) dated industry and news reports, used only for contract facts such as delivery schedules.

B. Inclusion. A source will be provided whenever there is a report on a contract fact, audited outcome, policy rule or theoretical result that affects performance, risk-sharing or accountability in defense manufacturing or equipment support. Opinion pieces lacking factual support are not included. Only the official release will be cited where both a news report and an official release give the same figure.

C. Evidence grading. Each case and assessment in sections IV-VI will be graded on the basis of which source type has been most influential: Audit, Official Statistics, Theory/Model, Policy Analysis or Press/Industry Report. The performance measurement will be based on audited evidence separate from the official claims by government agencies about their successes, since agencies report on performance in terms of output, not on whether that output is worth the money spent.

D. Framework construction. Sections III and VII are analytical on the PRA framework. Its equations are standard results in procurement theory [8, 15, 16]. No parameters are estimated and no simulated or synthetic data are used. Each condition derived is proposed as a testable proposition for future empirical work.

III. Partnership Models and Formal Basis

A. Six partnership models

Defence-manufacturing PPPs differ in who owns the asset, who operates it and who carries demand risk. Table 1 groups the arrangements found in the review into six models.

Table 1. Partnership models in defence manufacturing and support

Model	Asset owner	Operator	Main risk carried by the private partner	Example in this review
Availability-based PFI	Private SPV	Private SPV	Construction, availability,	UK Future Strategic Tanker Aircraft [17]

Model	Asset owner	Operator	Main risk carried by the private partner	Example in this review
			financing	
Government-owned, contractor-operated (GOCO)	State	Private firm	Operating cost and efficiency	US Army ammunition plants [18]; proposed UK DE&S GOCO [19]
Corporatised state producer	State company	State company	None transferred; commercial discipline sought	Seven DPSUs created from India's Ordnance Factory Board [20]
Strategic or industrial partnership	Private Indian firm, often with a foreign OEM	Private firm	Capital, technology absorption, delivery	DAP 2020 Chapter VII [21]; Tata–Airbus C295 line [22]
Privatised research partner	Private (with state stake at first)	Private	Commercial R&D risk	QinetiQ, from the UK Defence Evaluation and Research Agency [23]
Industrial corridor or cluster	Private firms on state-developed land	Private firms	Investment and market risk	Uttar Pradesh and Tamil Nadu corridors [24]

The models are on a spectrum. On the other hand, the state provides for the transfer of ownership and much of the risk, in contrast, the state provides for the retention of ownership and risk while only purchasing management efforts. The UK PFI and Indian Corridors are closer to the private side. Strategic alliances enable the state to maintain control over demand and design authority, while the private partner invests in capacity.

B. The Indian policy sequence

India moved from a near-public monopoly to a mixed model in four steps. In May 2017 the MoD added Chapter VII, "Revitalising Defence Industrial Ecosystem through Strategic Partnerships", to the Defence Procurement Procedure 2016 [25]. The chapter noted that aircraft, submarines, helicopters and armoured vehicles were then built by defence public sector undertakings (DPSUs) and the Ordnance Factory Board, and it cast the strategic partner as a private Indian system integrator [25]. The Defence Acquisition Procedure (DAP) 2020 kept the chapter and was issued alongside a rise in the automatic-route foreign direct investment (FDI) limit from 49% to 74% [21]. On 1 October 2021 the 41 production units of the Ordnance Factory Board were transferred to seven wholly state-owned companies [20]. Two defence industrial corridors, with six nodes in Uttar Pradesh and five in Tamil Nadu, were set up to attract Rs 20,000 crore of investment by 2024-25 [24].

Private partners will be involved in each stage of the process and are expected to bring in digital production methods. Besides automation, Industry 5.0 stresses the need for a human-centric and resilient manufacturing environment [26], [27]. This change will be significant for ministries as it will provide them access to performance related data from data rich plants. Such data will provide the needed basis for the contract models described in Section V.

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C. Formal basis

The framework uses three quantities: risk-adjusted value for money, the present value of payments, and the private partner's cost share.

Let C_b be the base cost of delivering a capability through conventional public procurement, R_t the expected cost of risks that a partnership would transfer, and R_r the expected cost of risks the state keeps under either route. The risk-adjusted public sector comparator is PSC = C_b + R_t + R_r. Under a partnership the state pays a stream of unitary charges U_t over T years and still bears R_r'. Value for money is

$$VfM=(C_b+R_t+R_r)-\left(\sum_{t=1}^{T}\frac{U_t}{(1+\delta)^t}+R_r'\right) \qquad (1)$$

where δ is the public discount rate. A positive VfM favours the partnership. Eq. (1) shows that the case for a PPP rests on R_t: if the transferred risk is overstated, or if R_r' exceeds R_r because the state takes back risks under renegotiation, the advantage disappears.

Holding the comparator's cash flows fixed, the sensitivity of Eq. (1) to the discount rate is

$$\frac{\partial VfM}{\partial \delta}=\sum_{t=1}^{T}\frac{t\,U_t}{(1+\delta)^{t+1}}>0 \qquad (2)$$

A higher discount rate flatters a payment stream spread over many years, because a capital-heavy public comparator is paid early while unitary charges arrive late, and the effect grows with T. For a 27-year contract such as the UK tanker PFI, a small change in δ can reverse the sign of VfM. Section IV shows that this happened.

The third quantity follows the linear-contract model used in PPP theory [8]. Realised cost is C = c_0 - e + ε, where e is the partner's cost-reducing effort, with private cost k e²/2, and ε is noise with variance σ². The state reimburses a share (1-β) of cost, so the partner bears share β. With constant absolute risk aversion ρ, the partner chooses e = β / k, and the state's optimal share is

$$\beta^{*}=\frac{1}{1+\rho\,k\,\sigma^2} \qquad (3)$$

A fixed-price contract is β = 1 and cost-plus is β = 0. Eq. (3) states that the private share should fall as cost uncertainty σ² rises. It also falls as the partner becomes more risk-averse or effort becomes costlier. The partner's risk premium, ρ β² σ² / 2, is the price the state pays for transfer. This is why PPPs typically show higher risk premia than conventional procurement [8].

D. Theoretical lenses

Two results from contract theory that explain why defense is different from civil infrastructure. According to Hart’s arguments on incomplete contracts, if the quality of the service provided by the private contractor can be defined and measured, then the bundling of the construction of the facility and its operation in a single private contract will give a stronger incentive to the private contractor to build quality. However, if the quality cannot be defined and measured, the private contractor will reduce the unmeasured quality to reduce costs [15]. It is not normally easy to pre-define defense capabilities. The threat can change what a requirement is, some quality aspects such as combat performance are only visible when the capability is used. According to Iossa and Martimort, the gains from bundling with private ownership are larger for generic facilities (e.g. accommodation) than for specific facilities with few uses outside the public sector [8]. Most defense manufacturing sites are dedicated sites. A military aircraft production plant or an ammunition factory doesn’t have many civilian buyers. Both of these findings therefore suggest that fully privately financed PPPs should perform best at the generic end of defense (housing, training areas, transportation services) whereas they will perform poorly at the specific end of defense production. The tanker PFI, based on a commercial airliner, was more toward the generic end of defense. In contrast, the GOCO (Government Owned Contractor Operated) and corporatization models are at the specific end of defense production as they keep public ownership of defense production facilities.

The final lens is the definition of the state. According to Bellais, Public Private Partnerships (PPPs), which were created in the United Kingdom in the late 1980s and early 1990s, redefined the boundaries between the public and private sectors in defense investment, and that the British model would be adopted by all other government departments in an effort to avoid budget cuts [10]. The framework developed in section III.C defines the boundaries as a choice from the six models of Table 1. The decision is made on a capability-by-capability basis, rather than on an overall sector basis.

IV. Performance (RQ1)

Performance is judged here against the baseline each auditor or ministry used. Three questions recur: did the partnership deliver the capability on time, did it cost less than the public alternative, and did it build lasting industrial capacity?

A. UK: audited outcomes of private finance

The UK tanker programme is the most closely audited defence PPP. In March 2008 the MoD signed a PFI contract with AirTanker for air-to-air refuelling and passenger transport based on 14 A330 aircraft, replacing 24 Tristar and VC10 aircraft [17]. The contract ran 27 years and was valued at £10.5 billion [17]. The NAO could not conclude that the procurement phase achieved value for money [17]. It reported that the PFI route was chosen in 1997 without a sound comparison of alternative routes, and that the department's own senior economic adviser stated in 2007 that the PFI would not represent value for money under a revised discount factor [17]. Negotiations took over nine years against an expected four [17]. The Committee of Public Accounts judged the use of PFI for the project inappropriate [28].

The tanker case demonstrates how risk that remains with the state is reflected in costs. The 2012 Major Projects Report indicated that the forecasted costs of the project increased by £336 million due to estimated increases in fuel prices over time, which were outside of the Department's control financially, but were partially reduced by a £98 million saving through refinancing the PFI contract [29]. Fuel represented a retained risk (R_r' in Equation (1)) that the initial comparator could not assess.

In terms of the entire portfolio of projects, there is a variety of different types of performance. While most of the PFI projects provide the services which they were contracted to provide, the NAO has continuously reported that there is no systematic and ongoing evaluation of whether the projects provide value for money and no evidence to demonstrate that PFI performs better or worse than alternative delivery mechanisms [5], [30]. Similarly, academic evaluations of PFI in the United Kingdom have come to the same conclusions: the savings claimed are primarily dependent upon the assumption of risk transfer made when comparing PFI to an alternative method of procurement [31], [6].

The UK GOCO reform is a performance result of a different kind: a partnership that never formed. In 2011 the MoD launched its Materiel Strategy to reform Defence Equipment and Support (DE&S), and chose the higher-risk option of converting it into a GOCO [19]. In December 2013 the competition was halted after only one bidder remained, and DE&S became a bespoke trading entity in April 2014 [19], [32]. The Materiel Strategy had cost £33 million by then [19]. Contestability, not contract design, was the binding constraint.

B. United States: GOCO production

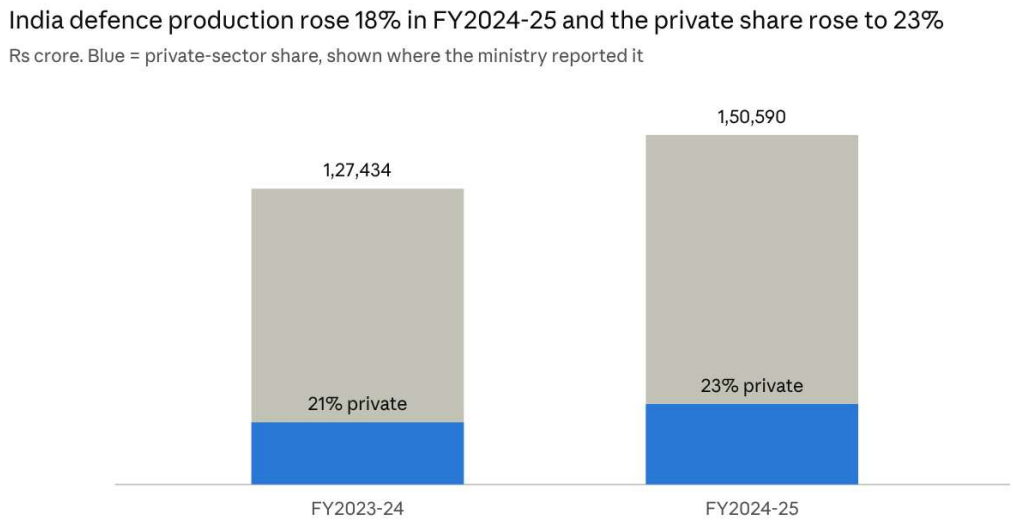
The US ammunition production base dates to the First World War [18]. The Army had 84 ammunition plants in the 1940s and, by 2022, ten organic facilities, seven GOCO and three government-owned and government-operated [33]. The Congressional Research Service identifies five principal GOCO plants that supply most of the military's conventional ammunition, propellants and explosives [18]. The model keeps surge capacity in public hands while buying private management. Its weakness is age: many plants date from or before the Second World War, which prompted a three-phase, US$16 billion modernisation plan for the organic industrial base [18]. A 2022 GAO review cited by the Congressional Research Service pointed to complex organisational

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relationships and outdated policy documents in the Army's management of the base [18]. Performance under GOCO therefore depends on the state's own investment and oversight, not only on the operator.

C. India: capacity building

Indian evidence is mostly official statistics and contract facts; no audit of a defence PPP's value for money was found. Fig. 1 shows the output trend that partnerships are meant to raise.



Source: Press Information Bureau, 9 Aug 2025 [3]; private values computed from the reported shares

Fig. 1. India's annual defence production, FY2023-24 and FY2024-25, with the private-sector share where reported [3].

The private sector share of production rose from 21% in FY2023-24 to 23% in FY2024-25. Production by private sector increased by 28% as compared to 16% increase in production by DPSUs [3]. Based on reported shareholdings, private sector output increased from around Rs 26,760 crore to about Rs 34,640 crore. Private sector firms also contributed to 64.5% of the total export supply [4]. All three of these data sets are measures of output and not measures of value-for-money. No of the data sets distinguishes between partnership contracts and regular private orders. The best example of a private sector assembly line set up with an Indian Government Contract in India is the Tata-Airbus C295 Program. On 21 September 2021, the Ministry of Defense (MoD) signed a Rs 21,935 Crore Contract for 56 Aircraft, of which 16 are to be delivered from Seville, Spain and 40 are to be produced in India [22]. The Vadodara final assembly line, inaugurated in October 2024, is India's first private-sector final assembly line for military aircraft [22]. The programme plans more than 85% of structural and final assembly in India, 13,000 detail parts, 21 certified special processes and 37 Indian suppliers, with all 40 aircraft due by August 2031 [34]. In May 2026 the first India-built aircraft was reported complete on the Vadodara line [35]. Delivery against the 2031 date is the test still to come.

Supplier depth is the long-run performance measure for such programmes. Digital supply-chain tools, including virtual models of supplier networks and AI-supported planning, are proposed as ways to monitor this depth and its resilience [36], [37]. No study was found that applies them to an Indian defence programme.

D. Transferability of the UK model

Several studies have asked whether UK results carry over to other ministries. A Naval Postgraduate School study of the MoD portfolio identified risk transfer as the key requirement for PPP success and assessed its applicability to the US Department of Defense [11]. A doctoral study of MoD PFI projects built an original dataset on the ownership and control of project companies and examined how the market for these contracts was structured [13]. Uttley examined how the MoD had

harnessed private capacity on deployed operations and concluded that both the MoD and the US Department of Defense had lessons to learn from each other [12]. Read together, these studies support transfer of the UK's contract tools, such as payment by availability and output specification, but not of its fiscal motive, which the NAO found had driven the tanker decision [17]. For India, where the motive is capability rather than budget relief [21], the relevant UK lessons are the audit trail and the comparator, not the financing structure.

E. Assessment

Information below was obtained from: - Six audit or Parliamentary reports in the UK - Two official statistical releases - Two U.S. policy documents - Four media/industry reports - Seven academic articles These sources do not indicate that goods/services acquired through defense PPPs are of higher value than goods/services acquired publicly. However, considering research question one, the evidence shows that defense PPPs can deliver required services, can develop additional capability, and, as demonstrated by the most heavily audited PPP project, did not yield better value than public procurement.

V. Risk Sharing (RQ2)

A. Which risks are transferred

PPP Risk Allocation – A general principle in allocating PPP risks is to allocate each risk to the party who has the greatest ability to manage the risk, or who can absorb the risk for the least cost [7], [38]. In a U.K. survey of construction projects under PPP/PFI, respondents stated their preferred approach to allocate most of the risks of the project to the Private Sector Partner, with some politically or legally based risks allocated to the Public Sector, and several risks allocated to both [38]. There are two other types of risk that Defense typically faces but are rare in civil PPPs. These include Requirement Risk (the State may change its requirements), and Surge Risk (in times of conflict, the State will require products made by a facility sized for commercial use, but that cannot meet the increased demand created by military operations). As such, these types of risks remain Public Risks for Defense because the Government Owned Contractor Operated (GOCO) arrangement enables the Government to retain ownership of the facilities used to produce items for use in Defense applications [18].

Table 2 compares the cases by what was transferred and what returned to the state.

Table 2. Risk transfer in reviewed cases

Case	Risk transferred	Risk retained or returned	Outcome	Evidence
UK tanker PFI (2008–2035)	Aircraft ownership, availability, maintenance, financing	Fuel price, requirement change	£336 m fuel cost rise in one year; VfM not shown	Audit [17], [29]
UK DE&S GOCO (2011–2013)	Procurement management (planned)	All, after competition halted	One bidder; abandoned	Audit [19]
US Army GOCO plants	Plant operation	Ownership, modernisation, surge	Supplies most conventional ammunition; plants ageing	Policy [18], [33]
UK QinetiQ	Commercial R&D	Independent technical advice	Possible effect on quality of technical advice to government	Academic [23]
India C295 line	Factory investment, local	Programme demand (fixed 56	Line built; first aircraft 2026	Press [22], [34]

Case	Risk transferred	Risk retained or returned	Outcome	Evidence
	supply chain	aircraft)		
India defence corridors	Plant investment	Land, infrastructure	14.5% of commitments grounded	Official/press [39]

B. Matching transfer to uncertainty

Equation (3) suggests that a high degree of cost uncertainty (σ^2) will result in a low level of private cost sharing. In contrast, if the cost uncertainty (σ^2) is low, private cost sharing will be high. This theory works well for the development of a new platform (high σ^2) and for the series production of a well developed platform (low σ^2). But there are examples which support the theory and there are examples which contradict it. One example is the government-owned, contractor-operated (GOCO) ammunition factories. These plants produce ammunition, a mature product with little uncertainty as to cost (low σ^2). A 1984 audit by the General Accounting Office (GAO) of these plants showed the Army was using several contracting methods to run them. Some of these contracts were cost-reimbursement contracts [40]. Hence, the β of these plants was low and the σ 2 was low as well . This caused the model to lose some efficiency to maintain control over surge capacity. Another example is tanker private finance initiative (PFI) in which the risk of availability of the mature airframe was largely transferred to the private sector (fitting Eq. (3)). But the state was still responsible for the most volatile cost of running the tanker, which was fuel.

Large scale defense projects suffer from the same problems of cost overruns as those seen on other large scale infrastructure projects (mega-projects) which have historically been prone to final costs exceeding the estimated cost [41]. If β is high, the partner is bidding the risk premium into the price. A low β means the state assumes the risk. In either case the danger is still there. Equation (3) merely identifies who pays for the risk and what that payment signifies.

The surge risk (the risk that the plant will not be able to produce enough ammunition) must be discussed separately from civil PPPs because this is where defense is most different from them. A commercial plant is built to provide only that amount of ammunition needed in times of peace. Idle capacity earns no income. The US Army tied contract reform for its GOCO ammunition plants to the ability to support large scale combat operations [42]. If the state were to use a private finance model, then the state would have to pay for the idle capacity directly. If the state uses the GOCO model, then the state pays for the idle capacity indirectly through owning the plants that operate at less than capacity in times of peace. Thus the selection of models decides where the costs appear in the budget, not whether they appear at all.

C. Renegotiation and hold-up

A second potential problem exists after signing. Since large contracts are usually not fully completed, both parties may agree to modify the terms of the agreement as conditions evolve [15], [16]. Let 's' represent the portion of the partner's investment in the defense customer, and 'p' represent the likelihood that the state will be able to locate an alternate supplier during the contract period. The state can realistically expect the partner to abide by the provisions of the agreement, provided that

$$p \cdot V_{alt} \geq (1-p)\, L_{gap} \qquad (4)$$

where V_alt is the cost to change suppliers and L_gap is the amount of capability that will be lost due to a gap in supply. If equation (4) does not hold true then the partner, not the government, has bargaining power. High levels of asset specificity (high s) cause a decrease in p, as there are few other companies that can take over. The single bidder outcome of the UK GOCO competition is an example of an extremely low p prior to signing the contract [19]. India's strategic partnership approach, which requires the strategic partner to be an Indian corporation and select partners from a limited list within each segment [25], [21], maintains a low p intentionally; it sacrifices contestability for domestic capability.

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D. Fiscal treatment

Risk sharing can also be seen from an accounting perspective. Future charges on existing PFI arrangements in the UK stood at £199 billion and will continue until 2040 [5]. Whether these liabilities would appear on the public balance sheet depends on whether the risk has been successfully transferred to the private partner. Accounting standards and the fiscal frameworks they comprise specify how these obligations are to be accounted for in financial reporting [43]. Where a PFI model allows accounting reporting that benefits a PPP, then the choice of PFI may be driven by budgetary considerations as opposed to the overall value provided. This is exactly what the NAO discovered when it evaluated the tanker program. That is to say, the PFI model provided the department short term affordable advantages [17].

E. Assessment

Of the six cases in Table 2, one transferred operating risk and had its performance audited (the UK tanker); one was audited but never established (DE&S); and the other four had no published value-for-money audits. The theoretical recommendation for PPPs in defense is to transfer availability and operating risks (RQ2). However, the risks of requirement, fuel and surge remain with the state and contracts that transfer risk primarily because of budgetary constraints have not shown value for money.

VI. Accountability (RQ3)

A. Dimensions of accountability

Accountability in a PPP means that each party can be required to explain and justify its conduct to a forum that can impose consequences. Six dimensions are used here: risk, costs and benefits, political and social impacts, expertise, collaboration, and performance measurement [9]. Accountability and value for money are linked: a partnership whose costs and risks cannot be inspected cannot show value for money [44]. PPPs also blur political responsibility, because ministers can attribute failure to contractors and contractors to contract terms [45].

Defence sharpens all six dimensions. Commercial confidentiality and national security both limit what can be published. Uttley found that the growing use of contractors on deployed operations affects public expenditure choices, accountability and the conduct of armed conflict, and called for greater independent scrutiny [12].

B. Mechanisms

Four mechanisms appear in the reviewed cases.

1. *External audit.* The UK case evidence in Section IV exists because the NAO and the Committee of Public Accounts audited defence PPPs after signature [17], [28]. This review found no published Indian audit of a defence PPP's value for money, which is why Indian evidence here is statistical.
2. *Internal audit and risk management.* Internal audit gives the board of each partner, and the ministry, an independent view of disruption risk and resilience during the contract [46]. Governance that ties capital allocation to stated responsibilities is part of the same structure [47].
3. *Ownership and step-in rights.* GOCO keeps ownership public, so the state can replace the operator without losing the plant. Corporatisation of the ordnance factories kept ownership but created company boards that answer for commercial results [20].
4. *Data and digital monitoring.* Control over production data and the systems that hold it is a form of sovereignty [48]. AI-assisted compliance monitoring [49] and data-driven institutional design [50] are proposed for regulated sectors; their transfer to defence partnerships is untested.

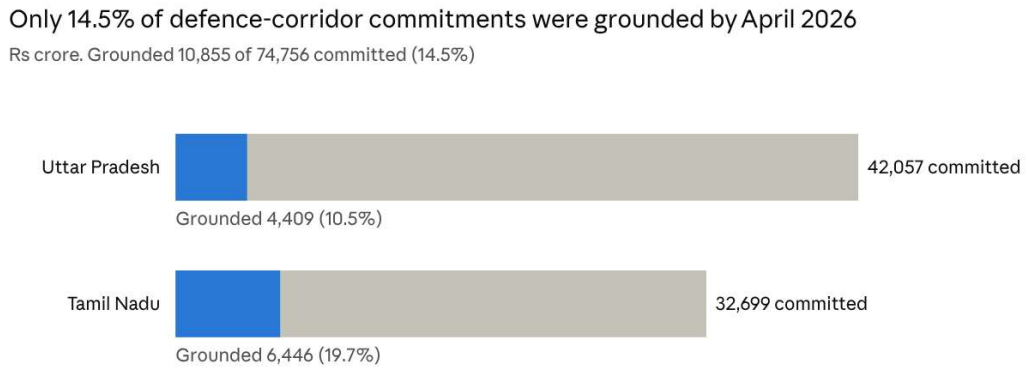
The privatised research partner raises a separate accountability problem. When the UK turned most of its defence research agency into the part-private QinetiQ, James noted potentially profound implications for the quality of the scientific and technological advice available to government [23]. Risk is inherent to structures where one organization provides advice to customers as well as sells products/services to those customers. In terms of responsibility/accountability [9], the "expertise" aspect of accountability exists when a government ministry has moved all of its engineering staff to another company; at that point, the government ministry cannot evaluate the accuracy of the other

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company's assertions. Similarly, there are risks with all types of partnerships where the government relies on a private organization for technical knowledge (design). Usually, the solution to this problem is to maintain a small internal technical department, and the expense associated with maintaining that internal technical department would fall under R_r' in Eq. (1).

C. Commitments versus delivery

Accountability for industrial policy needs a measure that separates promises from investment on the ground. Fig. 2 shows this gap for the Indian corridors.



Source: Defence Secretary figures as of April 2026, reported in [39]

Fig. 2. Investment commitments and grounded investment in the Uttar Pradesh and Tamil Nadu defence industrial corridors, April 2026 [39].

In March 2022 actual investment stood at Rs 1,552 crore in Uttar Pradesh against Rs 8,764 crore under memoranda, and Rs 2,217 crore in Tamil Nadu against Rs 11,103 crore [51]. By April 2026 commitments had grown to Rs 42,057 crore and Rs 32,699 crore, and grounded investment to Rs 4,409 crore and Rs 6,446 crore [39]. Grounded investment thus equalled 10.5% of commitments in Uttar Pradesh and 19.7% in Tamil Nadu. A ministry that reports commitments alone reports the denominator of a ratio whose numerator it does not publish.

D. An accountability condition

The mechanisms above can be combined into one condition. Let m be the probability that underperformance is detected by audit or monitoring, q the probability that detection leads to a sanction (penalty, step-in or non-renewal), and S the size of the sanction. A partner that can save G by underperforming will comply if

$$m \cdot q \cdot S \geq G \qquad (5)$$

Eq. (5) shows that each mechanism works only through the product. Publication and audit raise m. Step-in rights and contestable re-competition raise q, and q falls whenever Eq. (4) fails, because a state that cannot replace its partner will not sanction it. Large penalties (S) cannot compensate for q near zero. The narrow partner pool of the strategic partnership model therefore needs higher m, through audit and data access, to keep Eq. (5) satisfied.

E. Digital and workforce enablers

The management literature discusses two further enablers, though neither has yet been tested in a defence partnership. The first is the workforce that a partnership inherits or builds. Fourth-industrial-revolution technologies change the skills a modern plant needs [52]. Human digital twins and machine-learning talent analytics are proposed for planning training and predicting attrition [53], [54], and the division of work between people and AI raises its own leadership and ethical questions [55]. Workforce transfer is also an accountability issue: the move of ordnance-factory employees into seven new companies [20] resembles corporate restructuring in Indian aviation, where HR policies and legal compliance have been examined [56].

The second enabler is shared analytics. Ensemble forecasting for operational planning [57], AI-driven process modelling [58] and AI-supported operational and strategic decisions [59], [60] could

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make a partner's production data usable for the ministry's monitoring, which would raise m in Eq. (5). Partners will resist pooling sensitive data. Federated learning lets several organisations train a common model without exchanging raw records. It has been proposed for collaborative decision modelling in multi-unit enterprises [61] and for fraud detection across institutions [62], although its robustness to adversarial manipulation remains a concern [63]. Any algorithm used to rate partners would also need to be explainable [64] and checked for bias [65] before its outputs could support a sanction. These proposals come from finance and general management; for defence they remain untested assumptions, not evidence.

F. Assessment

In the UK case studies, external audit is identified as one of the four mechanisms of accountability employed by defense PPPs, while the US and Indian case studies document the use of ownership-based control and only the general management literature document both internal audit and digital monitoring. RQ3: Accountability in defense PPPs will be highest when the government retains ownership of the service/facility/product or has a realistic alternative supplier and when the independent auditor issues a public report after the contract is signed. The lowest accountability of a defense PPP will occur when the number of potential partners is limited and no public report is released by the independent auditor.

VII. Integrated Framework, Gaps and Limitations

A. The PRA framework

The three strands combine into one test. A defence PPP is justified when

$$\underbrace{VfM(\delta, R_t, R_r')}_{\text{Eq. (1)}} + \lambda \Delta I > 0, \quad \beta \approx \beta^* , \quad m\, q\, S \geq G \qquad (6)$$

where ΔI is the magnitude of the increase in national industrial capability, e.g. the addition of indigenous components or supplier certifications, and λ is the importance the state places on that increase. The first condition tries to determine whether the cost of the partnership is less than the cost that would have been incurred had there not been a partnership, given the risk on both options. The second condition recognizes that states like India will pay a premium in terms of cost to develop capabilities and λ provides a mechanism for quantifying that premium rather than obscuring it in an overoptimistic assessment of R_t. In addition, both conditions require that the fraction of costs allocated to each party is proportional to the degree of uncertainty in performing the work (Eq. (3)) and that the other party remains liable (Eq. (5)).

Eq. (6) yields three testable hypotheses. First, if the development contract is with β close to 1 instead of β close to β*, the contract bidding price will be higher and contracts will have more renegotiation. Second, models with a small number of possible partners, will result in less punishment for the same level of detected underperformance. This is because Eq. (4) will be violated more often. Third, success reports of industrial policy based on commitments made will always be higher than actual investments made, by a margin that shrinks when the actual figures are publicly available.

B. Research gaps

Table 3 lists the gaps found and the quantity each would require.

Table 3. Research gaps and the parameter to measure

Gap	Evidence in this review	Quantity to measure
No audited value-for-money study of an Indian defence PPP	All six audit sources are UK [17], [5], [19]	VfM of Eq. (1) for the C295 line and SP projects
Unpriced retained risks	Fuel inflation in the tanker PFI [29]	R_r' by risk type
Cost-share fit untested	No published data on β for defence PPPs	β versus σ^2 across contracts
Contestability not	One GOCO bidder [19]; Indian	p in Eq. (4) by segment

Gap	Evidence in this review	Quantity to measure
measured	strategic partners drawn from a shortlist per segment [25]	
Corridor delivery reported mainly as commitments	14.5% grounded [39]	Grounded-to-committed ratio by year and node
Capability gain not valued	Indigenous content targets only [34]	ΔI and the implied λ

C. Implications for Indian policy

The implications drawn from the conceptual framework and data are four-fold. The first is that the strategic partnership model must have a benchmark to report against. India is known to pay a premium for developing indigenous capabilities. This is represented mathematically by λΔI in Eq. (6). If λ were reported openly, instead of assuming all partnerships are successful, auditors could determine if the premium paid is commensurate with the capability gained.

Secondly, the type of contract should comply with the development stage of the program. The C295 family of products are built on a proven in-service design. The development process for this product line has low-σ^2 characteristic, and thus, under Eq. (3), there can be a large portion of the private costs that are covered by the private sector. But the submarine and fighter aircraft programs in the strategic partnership segments involve significant design and integration risks. The development processes for these programs will have a high σ^2 characteristic because of these risks. So if a big chunk of the program is fixed price, then the bidders are likely to put in higher prices for their proposals, or, on the flip side, fewer bidders will come forward with proposals.

Thirdly, post selection, the contestable nature of the partnership should be protected. We maintain a low value for “p” in Equation (4) by restricting the number of shortlisted partners for each segment [25]. But the state can again raise "p" by exercising step-in rights, technical data rights and qualifying second sources for key components. All of these will increase "q" in (5) but will not affect the partner.

Fourth, all industrial-policy reporting should include a ground amount for each commitment amount. Both types of figures appear in corridor data [51],[39]. If these ratios were published by each node, for each year (as Fig. 2 shows for state total ratios) then the Parliament would have a direct indicator of whether commitments are being delivered upon. The corporatized ordnance companies[20] are also an ideal candidate to use as a test case in addition. We can compare the financial reports of the boards, which now have commercial results, to the results of the private partners who operate in the same segment.

D. Adjacent literature outside defence

However, the larger literature on digital transformation in both Indian and multinational firms is beyond the scope of this literature review, but it can be used to inform future research about how partner organizations incorporate new methods. This literature covers research on digital and social media marketing [66]–[71], relationship marketing [72], customer interaction and immersive shopping experiences enabled by artificial intelligence [73], [74] and the role of service robots in branding [75]. Studies on digital payment adoption and immersive banking practices have looked at the adoption patterns of street vendors and retail customers [76]–[78]. Studies on AI applications on lending practices have compared credit risk model types [79], [80]. Entrepreneurship studies cover business practices under COVID-19 [81, 82], a regional business case [83], virtual incubation [84] and generative AI in executive decision making [85]. Workforce Literature: Predicts internal mobility of employees and monitors employee well-being [86], [87]. Methodology Literature: Reviews of human-in-the-loop reinforcement learning and quantum-inspired optimization techniques [88], [89]. In the literature on education, there are higher education, investments in educational technology, business and marketing education and international exchange programs [90]–[94]. In the literature on social and leadership issues, there are social isolation and empathy in leadership roles in the public sector [95], [96]. Sustainability literature includes carbon trading, environmental policies, green leadership, logistics for food distribution and electric vehicle mobility [97]–[101].

E. Limitations

Four limitations to the review First, the evidence is uneven: only in the UK are there audited results; for India there are official data and media reports; and some of the most important contracts are subject to confidentiality agreements. The second limitation is the geographic breadth of the review: we included only three countries, and the practices of France, Australia and Israel were not included. The third limitation is the search strategy was limited to open access audits and policy related publications which may underrepresent defense economics related publications that are behind a paywall. Finally, the PRA model adopted in the review is analytical. There has been no empirical measurement of the parameters (δ, σ^2, ρ, p, m, q, λ) of any defense PPP so far, which means that all the testable hypotheses identified above remain to be tested.

VIII. Conclusion

Defence ministries now use PPPs at scale, but the audited evidence that they deliver better value than public procurement does not yet exist. The UK auditor could not find value for money in a £10.5 billion, 27-year tanker PFI, and the UK attempt to run defence procurement through a GOCO ended with one bidder. India has raised private production to 23% of a Rs 1,50,590 crore total and opened its first private-sector final assembly line for military aircraft, yet only 14.5% of corridor commitments had been grounded by April 2026. The PRA framework explains these outcomes with three conditions: risk transfer must be priced in the comparator, the private cost share must fall as cost uncertainty rises, and sanctions must be credible, which requires an alternative supplier or strong audit. The next step is a published value-for-money audit of one Indian partnership, starting with the C295 programme, using the quantities in Table 3.

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