



# ‘Zero-error’ versus ‘good-enough’: towards a ‘frugality’ narrative for defence procurement policy

Kapil Patil<sup>1,2</sup> · Saradindu Bhaduri<sup>1,3</sup>

Received: 28 August 2019 / Accepted: 13 February 2020 / Published online: 27 February 2020  
© The Author(s) 2020

## Abstract

The procurement decision-making process for complex military product systems (CoPS) has significant implications for military end-users, suppliers, and exchequers. This study examines the usefulness of adopting a fast and frugal decision-making approach for the acquisition of military CoPS. Defence procurement environment is complex. On the one hand, there are uncertainties and severe resource constraints due to regularly changing threat perceptions, limited flow of information about new technologies, and the growing demand to reduce defence related expenses. On the other hand, several stakeholders remain pre-occupied with the demand for ‘zero-error’ technologies. In such a setting, recurrent cost overruns and delays in supply are common in defence procurement programmes, across countries. Taking the illustrative examples of the missile system, fighter jet, and radar system acquisitions in India, we elucidate on ‘optimising’ versus ‘satisficing’ dynamics in the procurement decisions. The paper argues that a fast and frugal decision-making process by relying on judgement, experiential knowledge, and intuitive learning might make procurement processes, adaptively, more efficient. Such an approach would enable a ‘good enough’ technology to be inducted, and improved upon, through regular feedback from the actual environment. The study has implications for policy scholarships on innovation policy instruments under uncertainty.

**Keywords** Defence procurement · Complex military systems · Frugality · Fast and frugal heuristics · Technology development

---

✉ Saradindu Bhaduri  
saradindu@mail.jnu.ac.in

Kapil Patil  
kapilpatil24@gmail.com

<sup>1</sup> Centre for Studies in Science Policy, School of Social Sciences, Jawaharlal Nehru University, New Delhi, India

<sup>2</sup> Science Diplomacy Programme, Research and Information System for Developing Countries (RIS), New Delhi, India

<sup>3</sup> International Institute of Social Studies (LDE Centre for Frugal Innovation in Africa), Erasmus University of Rotterdam, The Hague, The Netherlands

## 1 Introduction

Public procurement in recent years has emerged as an essential innovation policy tool across countries. The strong demand pool exerted by such public procurement serves as an important incentive for firms to undertake risks of R&D and innovation (Edler and Georghiou 2007; Lember et al. 2014). Traditionally, governments around the world allocate substantial resources to procure new weapon systems and military equipment through either ‘off the shelf’ purchase or indigenous development. The defence procurement environment, however, is complex. On the one hand, there are uncertainties and severe resource constraints due to regularly changing threat perceptions, limited flow of information about new technologies, and the growing demand to reduce defence related expenses (Dertouzos 1994; Sceral et al. 2018). On the other hand, several stakeholders remain pre-occupied with the demand for ‘zero-error’ technologies (See, Davis 2015; Gholz and Sapolsky 2000).

The decisions concerning the indigenous development and procurement of complex military systems (CoPS), in particular, have generated much interest owing to considerable uncertainty over technological choices, innovation, and their end-user acceptance. By CoPS, we refer to the systems, networks, infrastructure, engineering constructs and services that are highly costly and technology-intensive (Hobday 1998). Due to their ability to provide comprehensive situational awareness, the demand for newer and cutting edge CoP systems has intensely grown over the years. The procurement of such systems, however, is frequently marred with problems of time and cost overruns, performance gaps, and, at times, even a complete failure, resulting in substantial financial losses (Flyvbjerg 2011; Schwartz 2014; Bogan et al. 2017). Allegedly, the ‘optimisation driven’ end-user requirements and the demand for ‘zero-error’, often, lie at the core of such problems of time and cost overruns (Park 2012; Smith and Tranfield 2005).<sup>1</sup>

The paper examines the extent to which a heuristics-based frugal decision-making process can offer an efficient response to these problems. Under uncertainty, the ‘frugality’ approach emphasises on taking decisions based on heuristics and ‘simple rules of thumb’. A frugal approach prioritises “what works in the actual environment” over “what ought to work” (Gigerenzer and Todd 1999). In CoPS, such strategies might enable system designers, and procurement practitioners to respond to uncertainty emerging from lack of data for making ‘reliable’ predictions about cost, schedule and performance levels vis-à-vis the ‘highest’ specifications, interpreted to mean a preference for ‘satisficing’ over ‘optimization’ (Klein 2002). Here, frugality helps to yield satisficing solutions where a payoff reasonably meets the “aspiration” level (Simon 1967; Gigerenzer 2010). Over time, however, such solutions can be further improved through adaptive learning and incremental changes.

Section 2 analyses the institutional superstructure of defence procurement mechanism with a view to underline ‘optimisation’ as the underpinning dynamic. The necessities for an alternative framework, and the challenges to achieving it,

---

<sup>1</sup> In addition, firms underbidding, less than necessary time, etc. (also called as the “buy-in” tendency) have also been identified as other important reason (Alic et al. 1992; Latham and Hooper 2013).

are briefly pointed out too in this section. Section 3 elaborates on the conceptual framework of frugality and its importance in innovation and technological capability building efforts in CoPS. Section 4 outlines the research method and data sources, and analyses case studies of CoPS acquisition of missile system, fighter aircraft and weapon locating radar by the Indian authorities using the framework of frugality. The last section presents an analytical 'rounding up' and lays out a few policy instruments to infuse a frugality narrative in defence procurement.

## 2 CoPS and the procurement environment

The procurement of military equipment constitute around 40–45% of annual defence expenditure in many developed and developing countries (Tian et al. 2018). The procurement of "high cost, customized" complex product systems (CoPS) poses novel developmental, and procurement challenges due to their resource intensity and complexity (Hobday 1998; Markowski and Hall 1998). The CoPS products have a large number of customised components, and their production requires a broad range of knowledge and expertise (Prencipe 2000). With increasing complexity, the procurement of these systems encounters significant challenges in all countries. One significant source of the complication arises from the demand for 'zero-error' technologies by the involved parties in the procurement, often, irrespective of their affordability (Johnson and Johnson 2002; De Spiegeleire 2011). Below we discuss the superstructure and the environment of defence procurement mechanisms to understand how the demand for 'zero-error' emerges and sustains itself in procurement practices, across countries.

### 2.1 The demand for 'zero error'

A 'zero-error' approach presupposes that the new technologies and systems must be delivered with precision based on the stipulation of broad operational requirements (Davis 2015). Scherer (1964: 29), for instance, points out how the "incentives in weapons acquisition...ran strongly in favour of quality maximization and lead time minimization", ignoring, in turn, the aspects of costs. Rogerson (1995: 312) similarly argued that "the constant pursuit of improved performance and capabilities" constitutes the defining feature of defence procurement. In this pursuit, the military's natural choice for various weapons systems, Rogerson (1995) argues, is often biased toward "too high" a level of quality. The so-called, Gray (2009)'s pronouncement "Bid High Spec, Bid Full Spec" captures this dynamic most suitably.<sup>2</sup> Such practices are interpreted as rational, by the end-users, in the ever-evolving threat environment

---

<sup>2</sup> "Spec" is the short form for specification. In defence parlance, they are termed as QRs i.e. Qualitative Requirements or SQRs i.e. Service Qualitative Requirements.

of a nation. We now briefly discuss the factors, which lead to the demand for, and sustenance of, 'optimisation' and zero-error in defence procurement.

In the face of an evolving threat environment, existing defence capabilities are always perceived to be deficient. This gap pushes the end-users to demand 'the maximum' gains in the capability, perhaps, with the assumption that 'some' can only be obtained if one asks for 'a lot' (Gray 2009). The demand for the 'maximum' is often a typical response in a resource constraint setting, where existing resource scarcity makes one demand the 'excessive', whenever an opportunity arises<sup>3</sup>. The demand for highly "optimized" or 'battle-ready' systems is, therefore, legitimized, particularly when new acquisition opportunities come up infrequently. Moreover, the defence forces, in general, function within a 'zero-error' operational mindset, which drives them to seek the *best* achievable technological capabilities, *ceteris paribus*. The highly uncertain threat environment they work in, demands themselves to be battle-ready for any eventuality.

## 2.2 The critique of zero-error and the alternative approaches to procurement

Allegedly, the pursuit of 'zero-error' generates uncertainty about the system performance and entails delays and high risks of failures (Benett 2010). Brown (2013) terms such a practice as either unrealistic or cost-prohibitive. Many scholars and practitioners point out that it is hardly possible to determine the final system requirements (specifications) at a nascent phase of capability building, particularly for CoPS (Rich et al. 1986). Besides the quality parameters, the procurement process involves optimising the life-cycle cost (LCC) during the early stages of designing the programme (Lorell and Graser 2001). This exercise requires perfect knowledge of the costs of acquiring, owning, maintaining and the disposal of the system for its entire lifecycle (Pickup et al. 2010). In reality, these estimates often go way off the mark as they fail to take into account many uncertainties. The specifications once approved, however, become the statutory basis for assessing all the subsequent steps of a procurement process, irrespective of even the changing operational environment of the user (Hartley 1998). Audit agencies too, as mandated by legal and policy regime, evaluate the systems and contractual outcomes only by the approved requirements. The audit of the 'financial transactions' and 'operational performance' often contains findings, which are politically unpalatable and puts the pressure on congressional or parliamentary bodies to demand 'accountability' in the procurement decisions.<sup>4</sup>

The developmental cycles of many complex systems last longer than a decade. During this period, incidentally, many, initially thought essential, requirements either change or become unviable. In such a setting, the need for preparing and

---

<sup>3</sup> In poverty research, a similar phenomenon is often termed as 'the audacity of hope'. Here the aspiration of poor people increases, even though they remain unmet when they get exposed to the improvement possibilities.

<sup>4</sup> This applies, even when, ironically, a few requirements become obsolete along the way (See, Markowski and Hall 1998).

announcing a precise and detailed system performance requirement, at the outset, proves to be deeply flawed (Wellman 2003; Kausal 1999)<sup>5</sup>. As the estimates go awry, recriminations occur among the acquisition authorities, users, and contractor communities over who was at fault (*ibid*), undermining further the credibility of the whole process of cost calculations.<sup>6</sup> In a nutshell, the institutional structure of procurement acts as a critical driver of the 'zero-error culture' prevailing in the procurement environment. The unmet specifications, often, become a source of conflict between the system designers, procurement authorities, end-users and the oversight bodies (Lorell et al. 2006).<sup>7</sup> As a result, defence procurement authorities, across countries, seem to bid for the highest possible capability, to be delivered within a given timeline, 'at one go', in an undifferentiated manner (Gray 2009). Incidentally, the quest for such 'top of the line' capability often leads to rejection of available operationally useful technologies, along the way (Wylie et al. 2006; Gray 2009).

### 2.3 Spiral development and evolutionary acquisition: some new directions in defence procurement

In recent years, the policymakers in leading military hardware producing countries, such as the U.S., attempted to resolve these problems in technology procurement by adopting the so-called "evolutionary acquisition" and "spiral development" (Lorell et al. 2006). The U.S. Department of Defence (DoD), for instance, enacted the new 5000 series acquisition directives and instructions in the year 2003, which mandated evolutionary acquisition (EA) strategies as the "preferred approach" to satisfy the operational needs. In contrast to the previous approach of waiting long for 'total package procurement', EA aims at procuring a 'good enough' (operationally useful) technology early. The procured technology is then adapted and improved upon, step by step (DoD 2000). In the UK, along the similar line, an independent report for the Secretary of State for Defence called for fielding '80%' of the capability requirement as 'good enough' candidate for procurement, to minimise overruns in cost and schedule (Gray 2009). Indeed, a growing body of scholarship on system engineering suggests that systems are becoming increasingly complex, due to enhanced need for flexibility and incorporation of ICT. According to Gorod et al. (2017),

<sup>5</sup> The induction of these systems, however, remains contingent upon their accurately meeting the original specifications.

<sup>6</sup> The reliance on optimised tools of decision support is found to be of limited value in other context too. For instance, a study on customer management processes in leading Nordic retail banks reveal that managers often rely on simple rules of thumb and their local knowledge about customer behaviour, over the mainstream analytical approaches such as Customer Life Value calculations. See, Persson and Ryals (2014) for detail.

<sup>7</sup> In India, for instance, a parliamentary democratic process requires the National Auditor i.e. the Comptroller & Auditor General (CAG) to assess all the acquisition programmes for their outcomes against the approved performance parameters and tables the Performance Audit Report in the Parliament. The discrepancies recorded by the CAG in its audit are frequently reported in the media, thereby generating flurry of allegations between the military, industry, and the government over unmet requirements, cost and time overruns.

decision-making approach in such a scenario needs to evolve significantly.<sup>8</sup> Amidst the growing complexity of systems, the ability to find the best outcome reduces considerably. The system designers in such situations take decisions based on ‘what works and what does not’ in the actual environment (Salmon 2015).

This so-called evolutionary approach nevertheless proved to be inadequate in resolving the problems of cost and time overruns mentioned above. At times, the approach led to serious ambiguities in implementation, and organisational conflicts over ‘requirements management’, ‘cost analysis’, ‘budgeting’, and ‘auditing’ (Sylvester and Ferrara 2003). A Rand Corporation study by Lorell et al. (2006) notes that the logic of ‘spiral procurement’ often remains under-appreciated within the superstructure of procurement. The key stakeholders, such as the politicians, military users and auditors involved in the procurement process continue to demand for disclosure of exact time and cost structures associated with the end-stage capability in advance. Besides, the so-called evolutionary structure does not leave out the use of various ‘optimisation logic’ (e.g. use of Life Cycle Cost approach, and the rigid rules of operation) in the setting, giving rise to inherent incompatibilities between the different components of the institutional architecture of procurement.<sup>9</sup>

### 3 Optimisation, frugality, and complex systems

#### 3.1 A framework for analysis

The discussion in the previous sections clearly shows that optimisation refers to the selection of the *best*, or the one with the highest expected utility (Klein 2002). The limitation of this approach has been well recognised in the literature on bounded rationality (Klein 2002; Simon 1972). Herbert Simon notes that “the computational requirements for optimizing are usually too high for decision-makers” and hence “it is not always possible to optimize” (Byron 1998; Klein 2002). According to Simon, human rationality is bounded due to constraints such as complexity of the environment, incomplete information, limited cognitive capacity of information processing, and the limitation in time and other resources. As a consequence, human decision-making is often not quite clear-cut or ‘logical’ (Simon 1956). Klein (2002: 103) describes the tendency among decision researchers and practitioners to cling, tenaciously, on to optimisation as “fiction”. He argues that “there is not a way to determine if a decision choice is optimal owing to time pressure, uncertainty, and

<sup>8</sup> Snowden and Boone (2007) identify four levels of complexity, namely simple, complicated, complex, and chaotic. In this categorization, the simple and complicated systems are reckoned to be similar as both largely deal with the ‘knowns’ domain. In relatively simpler systems, it might be cost-efficient to conduct optimization. The complex and chaotic systems, however, concerned ‘unknowns’ situations where definite answers are elusive and decisions have to be based on incomplete information.

<sup>9</sup> In so far as evolutionary mechanism refers to a non-optimisation process, the framework adopted in these studies perhaps demonstrates a weak conceptualisation of the term ‘evolutionary’ in this branch of policy scholarship. See Witt (2003) for a detailed exposition of evolutionary policymaking. We get back to this issue in the last section.

ill-defined goals". In certain types of complex situations, there is no way to identify all of the available options due to rapid changes in the given environment, calling for using heuristics over optimisation to deal with such eventualities (Mousavi 2018; Gigerenzer 2005).<sup>10</sup> The public policies premised on the logic of demanding or selecting 'the best' thus risk imposing unwarranted costs, and, at times, maybe unaffordable to implement (Gigerenzer and Kurzenhaeuser 2005). Nevertheless, the dream of optimization (i.e. "selection of the best among all available options for achieving best results"), continue to drive policy decisions in many public and private domains (Klein 2002).

As opposed to optimisation, the frugal approaches emphasise upon 'economizing' the resources needed for decision-making. Its prescriptions, on the other hand, require an in-depth knowledge of institutions and relations operating in a given context, under resource constraints and uncertainty (Bhaduri et al. 2017). In several decision settings, information failures are widespread, and the 'fast and frugal' heuristic decisions, based on intuition, experience, learning, and gut feeling can be highly efficient (Gigerenzer 2008a, b, 1999). The works of Gigerenzer and his colleagues (Gigerenzer 2008a, b; Gigerenzer et al. 1999) are particularly significant, in this context, for bringing both the 'person who takes the decision' and the '(actual) environment in which the decision is taken', at the center of the discourse on decision-making under uncertainty.<sup>11</sup>

The 'fast and frugal' heuristics are, however, not "omniscience". The effectiveness of these heuristics depends both on the person who takes the decision, and the environment in which the decisions are taken. Cognitive factors like 'experience', 'adaptive aspirations', 'learning capacity' importantly shape the effectiveness of these heuristics.<sup>12</sup> In this conceptual schematic, the idea of frugality mainly refers to the 'simple search rules' and 'need satisfaction', as opposed to 'optimising under constraints'. Frugality, therefore, not only underscores 'what' is achieved but also

---

<sup>10</sup> Etymology of the word 'heuristics', as an adjective, refers to "serving to discover or find out". As noun, it is "that which is found unexpectedly". For our purpose, we would like to highlight that 'heuristics', etymologically, refers to the use and application of human mind and cognition, relying on intuition, judgement and expectation. (See etymonline.com for detail, accessed on 14 August 2019). Another, perhaps more dominant, tradition of use of heuristics is linked to actions based on habits and memory. Since cognitive underpinnings of routines and habits are not always clear, we confine to the first kind of use of the term. This use, in our view, makes the connection between heuristics and frugality more direct.

<sup>11</sup> It is important to note here about the ensuing debates in the scholarship on heuristics, often terms as "heuristics Debate (HD). HD refers to the differences in point of view on heuristics between the proponents of heuristics and biases (H&B) approach and the fast and frugal heuristics approach (F&F). Kelman (2011) examines this debate and its implications for the policymaking. According to H&B proponents, people "will not always make accurate judgments even if they have perfect information" due to their computational incapacity, and such heuristics based decisions, in most cases, remain biased and sub-optimum. On the other hand, the F&F scholarship claims "the key source of the use of heuristics is not our computational incapacity but our evolved capacity to make use of appropriate environmentally available cues". Decisions reached through such cues and judgments, especially under uncertainty, are 'ecologically rational' and have better predictive precision.

<sup>12</sup> Kheirandish and Mousavi (2018) point out the importance of tacit knowledge of decision-makers in this regard.

‘how’ it is achieved to obtain an ‘ecologically rational’ outcome (Gigerenzer 2008a, b). Such a process of decisionmaking would involve the following:

1. a search process using simple hierarchical steps and intuitive reasoning.
2. efforts to adapt to the environmental challenges through the demonstrated capacity for learning and imitation; and
3. an emphasis on actual performance, practicability, and effectiveness rather than logical/scientific validation (Bhaduri et al. 2017).

### 3.2 ‘Frugality’ in innovation

According to Nathan Rosenberg (1976), a seminal historian of technology, the innovators are seldom able to produce the systems or complex machines to the “special and exacting requirements and specifications of the (machine) users” (Rosenberg 1976:12). Due to large-scale uncertainty in realising the user requirements, the machine developers muddle through incrementally, often, at the shop-floor level, rather than being able to produce the system at “one fell swoop” (Rosenberg 1976).<sup>13</sup> Subsequent scholarship in the tradition of evolutionary economics has indeed identified uncertainty as a defining characteristic of the environment in which innovation is carried out. So far as the “rationality” of actors is bounded in such an environment, the agents try to pursue innovation through learning, adaptation, and trial and error (Nelson and Winter 1982). Heuristics come handy in such situations (Kheirandish and Mousavi 2018).<sup>14</sup>

Incidentally, while the need for trial and error, learning and adaptation is, by now, well recognised in the context of major, frontier, innovation, their relevance for a technology catch-up process is often viewed with suspicion, at least in the mainstream innovation and policy scholarship. To be precise, we argue that an appreciation for learning, adaptation and trial and error in inherently incremental innovation-led technological catch-up has witnessed an inverse U-shaped enthusiasm among scholars and policymakers. While such an appreciation grew in the decade of 1980s and 1990s, the post-WTO policy environment has often belittled such activities by clubbing them as ‘imitation’ or ‘piracy’, ideally to be done away with. The homogenization and strengthening of intellectual property rights and related regulatory architectures policies in this period have undermined the risks and uncertainties in the catch-up environment. Policymakers in such an environment are often persuaded to ‘buy from the readily available technology shelf’ from the advanced industrial countries. This perception emboldens the defence technology users in

<sup>13</sup> According to Joseph Schumpeter radical innovations can create whole new market segments and often creates challenges, for incumbent companies. Therefore radical innovations put high demands on existing companies to approach new challenges in novel ways and acquire new technological and business related competence compared to what they previously had.

<sup>14</sup> Humans, it is argued, are simply not able to calculate the consequences of all possible actions and choose between them in the way neoclassical economists usually assume.



these countries, for instance, to demand “*get me what I saw at... a defence expo, brochure or magazine article*” (Johnson and Johnson 2002, emphases added).

We, therefore thought it proper to present a snapshot of the literature on technological capability-developed since the 1908s-to proceed further. Lall (1987) defines technological capability as the, sequentially developed, capacity to select, absorb, assimilate, adapt, imitate, and improve upon, given (imported) technologies, which could eventually culminate into capabilities to create new technologies. This process underlines the importance of “uncertain environment”, in which minor innovations at the shop floor level contributes to the accumulation of technological capability, through creative adaptation or technological effort (Lall 1992).<sup>15</sup> Nelson (2008) locates such arguments within the broad premise of the evolutionary theory of innovation.

Note that the uncertainty in the environment, emphasised by this scholarship, would be even more relevant for catch-up in complex product systems for obvious reasons. Defence CoPS innovation environment, in particular, remains marred with uncertainties due to its strategic importance, which leads to an abysmally low level of information sharing about these technologies. Any innovation in this sector would have to rely significantly on adaptation, learning by doing and trial and error.

## 4 Data, research methods and the cases

India has followed a policy of promoting technological self-reliance in the defence sector through import substitution and indigenous technological capability building.

### 4.1 Data and research methods

We analyse three case projects undertaken by India's Defence Research and Development Organisation (DRDO) in collaboration with the various public and private sector defence companies. The study draws upon both primary and secondary sources of information. The primary sources include interviews conducted with in-service and retired senior officials from DRDO, Ministry of defence and the defence companies during 2015–19. We also conducted discussions with officials from the defence 'service headquarters' to obtain users perspectives. From each organization, we chose 2–3 officials with procurement, R&D, and development related portfolios. These interview schedules mostly had open-ended questions, and each interview lasted for about 45 min to 1 h. In some instances, the interviews were followed up through emails, telephone calls or personal visits for validation and obtain additional information. The data from such interviews were supplemented with the data available in the public domain in the form of questions raised in Indian Parliament, and the various reports of India's main audit body, the Comptroller and Auditor General

---

<sup>15</sup> This framework has been developed analysing the experiences of countries in Latin America, Mexico, Japan, East Asia and India. For a review, see Fransman and King (1984), Katz (1984), Gonsen (1998), Ray and Bhaduri (2001).

(CAG).<sup>16</sup> For understanding the broad contours of satisficing parameters and behaviour in indigenous technology projects, the real-life decisions were examined critically (Glockner and Betsch 2008).

## 4.2 The cases

### 4.2.1 The Akash Missile project

In the 1980s, India faced a severe shortage in its air defence capability as the existing systems imported from the Soviet Union in 1960s became increasingly obsolete, and needed to be replaced by new-generation systems. In 1983, the Ministry of Defence (MoD) commissioned an indigenous technology procurement project to the DRDO for the development of two Medium-Range Surface-to-Air Missile (MRSAM) systems named “Akash”, one each for the army and the air force.<sup>17</sup>

Being the first of its kind to be developed in the country, the project involved many uncertainties. The DRDO followed an incremental approach to develop the system and improve it further through a series of user-trials and feedback. After its commencement in 1983, the developmental tests were carried out during 1989 and 1997. During the initial user trials of the system in 2004, however, only Air Force participated while the Army chose to stay away, as the version was to be tested, apparently, yet to meet their specification requirements. In repeated trials up to 2004, the air force rejected the Akash even though the missile repeatedly struck its targets, the lead project developer revealed to us. During the period 2005–2006, the missile was tested as many as 16 times to demonstrate its interception capability against two live aerial targets and to establish its high accuracy and precision. Another official revealed to us that the strike probability of the missile, over time, has increased from 80 to 88 to 98.5%. Nevertheless, the stakeholders in the procurement ecosystem insisted upon the acquisition of complete capability, at one go, significantly delayed the induction of the complete system within a pre-defined timeframe.

The Air Force’s demand for meeting optimum performance and complete development multi-mode capability significantly delayed the first induction. It is only in 2008–09, the air force agreed to procure the two squadrons of Akash after a set of trials in December 2007 (Shukla 2009). Similarly, the army too, being skeptical about the specifications, agreed to induct the system in the year 2012 only after conducting its own trials in 2011.

Explaining the zero-error dynamics in the indigenous technology procurement, the MoD official with several years of experience in defence acquisitions remarked that in short-range missile systems, the DRDO has come to face stiff competition

---

<sup>16</sup> CAG has the sole constitutional authority to audit all receipts and expenditure of the union and federal governments, including those bodies and authorities substantially financed by the government. See [https://en.wikipedia.org/wiki/Comptroller\\_and\\_Auditor\\_General\\_of\\_India](https://en.wikipedia.org/wiki/Comptroller_and_Auditor_General_of_India), accessed on 14 August 2019.

<sup>17</sup> “Akash” meaning “Sky” was considered to be the apt name for this missile system intended to defend the skies for a range of 25 KM. For a short-range air defence system, the 25-KM range was determined to be suitable and was chosen as the initial specification after consultations with the end-users.

from foreign vendors.<sup>18</sup> This reinforced the demand for zero-error, as any failure to meet the zero-error specification by the DRDO would have strengthened the call for importing the technology from abroad. However, the users, for long, did not share the DRDO's assessment that Akash system fully met their 'operational' requirements. In this case, while the procurement superstructure conforms to the logic of frugality in allowing the scientists to indigenously develop the technology, it remained reluctant to procure the same, unless the zero error condition is met.

The case of AKASH project suggests that the preoccupation with optimisation limited the opportunities for feed-back based learning and incremental technology development. The procurement superstructure did not accord much flexibility for meeting the desired specifications, frugally. By refusing the early induction of the initial version of the missile, the procurement policy, arguably, delayed sequential development of the system through learning and technological upgradations.

#### 4.2.2 Light Combat Aircraft (LCA)

The Light Combat Aircraft (LCA) is among the few success stories among late-comer industrializing countries for undertaking the developmental of fourth-generation fighter aircraft. Although the project was conceived in the year 1983, it received the official sanction only in the year 1993. Interesting to note that only the 60 per cent of the requested budget was sanctioned to develop two non-weaponised technology demonstrators.<sup>19</sup> Only after the successful demonstration of first technology, the MoD sanctioned the remaining budget in the year 2001 for developing the concurrent fighting systems. According to many analysts and practitioners, the two-part developmental approach unduly delayed the developmental cycle of the LCA project (Shukla 2016). Being a CoPS project, the LCA development process has mainly relied upon learning by 'trial and error'. Besides in-house learning-by-doing efforts, the DRDO forged collaborations with other S&T institutions, local industry, and academia for solving critical challenges of indigenous development.

In its current form, the LCA represents a 'fourth-generation plus' fighter aircraft and incorporates full networking capabilities developed by the Indian defence establishment. Most importantly, the LCA is considered to be most suitable for network-centric warfare, as it can easily be integrated into the network of indigenously developed radars and sensors, which the imported systems cannot meet. According to many credible estimates, the LCA at the cost of USD 1.2 billion offers itself as highly cost-competitive compared to rival systems in the global market (Thiagarajan 2017). Similarly, performance-wise, the LCA has proved itself to be superior in many critical parameters compared to other fighter jets like Mirage 2000 and Mig 29

---

<sup>18</sup> The foreign vendors were willing to offer India latest air-defence systems, including the American Patriot system.

<sup>19</sup> Unsure about the feasibility of developing the entire capability and also out resource crunch, the MoD asked the Air Defence Authority to merely develop only the prototype capable of lifting-off without any fighting ability.

(BIS) (Karnad 2017a, b). According to a lead scientist, the LCA aircraft has already achieved over 3000 h of flight-testing remarkably well.

The ongoing developments to the aircraft structure are primarily aimed at reducing its weight and improving the engine and aerodynamic performance in order to make it a more robust system as demanded by the air force. He also emphasized that only an indigenously developed system such as the LCA, can offer a “secure” and “interoperable network-centric capability”. The LCA, this way, enjoys a distinct advantage over its foreign competitors. Notwithstanding such advantages, the procurement superstructure has withheld its induction in their quest for optimum capability. This delay, according to the experts, means a failure to appreciate the incremental, adaptable nature of technological change. The emphasis on acquiring the latest configurations (in terms of maneuverability and firepower) ‘at one go’ means that the procurement superstructure continues to prefer optimization over inter-operability. The developer strongly emphasized that a spiral procurement would not only have fulfilled the immediate operational requirement but also open up export possibilities through *the demonstrated* capacity of its efficiency. The policy approach has, once again, overlooked the importance of *incrementality* in innovation, thereby, causing cost and time overruns—all in the quest for ‘zero-error’ and optimality.

### 4.2.3 Weapon locating radars

The in-house development and procurement of Weapon Locating Radars (WLRs), shows how frugality driven approaches can fructify into an ‘operationally useful’ military systems with minimal costs and time overruns. In the 1980s, the Indian army had projected a requirement for fielding fire-finding radars and, in late 1980s, it reportedly decided to purchase the American AN/TPQ-36/37 radar. After a series of failed attempts to import the American radar, the MoD decided to commission the DRDO and BEL for its indigenous development.<sup>20</sup> According to a former official, the indigenous project, however, did not receive the sanction immediately, with users being sceptical about the ability of the DRDO to deliver the radar in time. The ensuing ‘buy’ vs ‘make’ dilemma had, reportedly, cost the country during the ‘Kargil conflict’, in which many Indian soldiers lost their lives due to their inability to detect enemy positions in high mountainous terrain.<sup>21</sup>

The WLR developmental project, nevertheless, witnessed a unique developmental pathway. During the tests of the Akash missile, the DRDO engineers ‘accidentally’ observed that the ground radar (named Rajendra radar), a key component of Akash system, was able to detect and track artillery shells being test-fired at a nearby range. Using a ‘similarity heuristic’, based on intuitive observation, and domain knowledge, the LRDE scientists, proposed to adapt the Array antenna of

<sup>20</sup> On two separate occasions, i.e. in 1989 and 1995, India had approached the foreign vendors for importing the WLRs.

<sup>21</sup> In the Kargil Conflict, as many as 700 Indian soldiers lost their lives, and almost 80 per cent of Indian casualties during the war were reported to have caused by the undetected enemy artillery fire.

the Rajendra Radar for the WLR, which eventually got sanctioned (Subramanian 2012).<sup>22</sup>

The procurement superstructure relied upon the experiential knowledge and expertise of DRDO scientists. It commissioned a mission-mode project for developing the radar system, including the antenna and key components indigenously. Bypassing the demand for acquiring a fourth (latest) generation high-accuracy radar (the US-made AN/TPQ-37 radar), the procurement superstructure went ahead with a locally made, third generation radar with 'operationally useful' efficiency in target detection. Incidentally, neither the users nor other stakeholders insisted on 'zero-error' for its procurement, even though the demand for the imported radar has not put off the list, till date.

## 5 Frugality-based heuristics in Defence procurement policy: a summing up

This paper has attempted to provide an understanding of the application and relevance of fast and frugal heuristics in the context of development and procurement of complex military systems. We find that while a certain degree of frugality was allowed concerning the decisions of allowing indigenous development of CoPS technologies, the 'optimization logic' looms large about the final procurement and use.<sup>23</sup> The research reveals that procurement policies, which are heavily biased towards achieving "zero-error" "at one go", discourage sequential learning through user-producer feedback, eventually leading to severe cost and time overruns, and failures. The optimizing tendency on the part of the military users, policymakers, audit agencies and, perhaps, the political establishments limits the scope for heuristic-based decision-making and thereby impose serious learning and opportunity costs on the indigenous defence innovation ecosystem. We argue that such tendencies to rely on optimization would possibly be higher in a technology catch-up country for which, the 'technology shelf' is presumed to exist and available to draw upon without much hassle. It is, therefore, not surprising that an appreciation for innovation-related uncertainties remains absent among the procurement stakeholders in a country like India. As Johnson and Johnson (2012) points out "get me what I saw at... a defence expo, brochure or magazine article" becomes a common syndrome in such a scenario.

Bringing back the discourse on technological capability, we reiterate the limitation of such an assumption and emphasise that incremental innovations too are prone to significant risks and uncertainties. This is particularly true for defence technologies for which information flow is inherently inadequate. It is, therefore, crucial for procurement policymakers to adapt to the realities of innovation uncertainties and adopt sequential (incremental) approaches and learning in procurement

<sup>22</sup> A subset of 'representative heuristic'. See Reed and Grushka-Cockayne (2011) for detail.

<sup>23</sup> Note, however, that we have not explored in detail how the scientists adopt 'fast and frugal' rules in the various stages of an innovation project. This requires further research.

decision-making based on feedback from the ‘actual’ environment of use. In some countries, this has been initiated in the form of ‘evolutionary acquisition’ and ‘spiral development’. In our view, however, these approaches reveal significant methodological incongruence. While adopting the term ‘evolutionary’, they continue to repose faith in the various optimization-based methods of cost calculations. A fast and frugal approach, on the other hand, has the potential to embrace the logic of evolutionary policymaking, as illustrated by Witt (2003), more fully, since both streams of scholarship share the common theoretical premise of bounded rationality, learning and adaptation to achieve a *satisficing* outcome.

Indeed, combining the thoughts of frugality and evolutionary policy discourse, one could ponder upon the following takeaways. First, there is a need to promote the scope of ‘learning along the way’, especially for policies in the areas of innovation and capability building. The emerging policy instrument of ‘spiral induction’ could achieve this if configured around the nuances of frugality and non-optimization. Secondly, and finally, encouraging interactions between the users, producers and regulators of technology from the very beginning could help to develop a shared understanding of the need for adaptation and incremental learning in the course of innovation, eventually, reducing the reliance on optimization based ‘zero-error’, and paving way for a judicious use of economic resources.

**Acknowledgements** We are thankful to the anonymous reviewers and the editors of the special issue for their critical constructive comments. The views and insights shared by Arvind Gupta and W. Selvamurthy have enriched the discussion of this paper immensely.

**Funding** No funding was received for the work.

## Compliance with ethical standards

**Conflict of interest** The authors declare no potential conflict of interest.

**Informed consent** All interviews were conducted with informed consent and after mentioning that the objective of collecting information is purely academic in nature.

**Open Access** This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if changes were made. The images or other third party material in this article are included in the article’s Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article’s Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit <http://creativecommons.org/licenses/by/4.0/>.

## References

- Alic JA, Branscomb LM, Brooks H, Carter AB (1992) Beyond spinoff: Military and commercial technologies in a changing world. Harvard Business Press, Brighton
- Bennett F (2010) The seven deadly risks of defence projects. Secur Chall 6(3):97–111

- Bhaduri S, Sinha KM, Knorringer P (2017) Frugality and cross-sectoral policymaking for food security. *NJAS-Wagening J Life Sci* 84:72–79
- Bogan MR, Percy AS, Kellermann TW (2017) Failure is not an option: a root cause analysis of failed acquisition programs. Naval Postgraduate School Monterey, New York
- Brown ML (2013) Affordability: preventing cost growth in DoD's Military capability portfolios. Army War College, Carlisle
- Byron M (1998) Satisficing and optimality. *Ethics* 109(1):67–93
- Davies C (2015) Understanding Defence procurement. *Can Mil J* 15(2):5–15
- De Spiegeleire S (2011) Ten trends in capability planning for defence and security. *RUSI J* 156(5):20–28
- Department of Defense (2000) Operation of the acquisition system (DoD Instruction 5000.2), October 23, Washington, DC
- Dertouzos JN (1994) Introduction. In: Bower AG, Dertouzos JN (eds) *Essays in the economics of procurement*. Santa Monica, RAND, National Defense Research Institute, pp 1–17
- Edler J, Georgiou L (2007) Public procurement and innovation—resurrecting the demand side. *Res Policy* 36(7):949–963
- Flyvbjerg B (2011) Over budget, over time, over and over again: managing major projects. In: Peter W, Morris G, Pinto JK, Söderlund J (eds) *The Oxford handbook of project management*. Oxford University Press, Oxford, pp 321–344
- Fransman M, King K (eds) (1984) *Technological capability in the third world*. Springer, New York
- Gholz E, Sapolsky HM (2000) Restructuring the US defense industry. *Int Secur* 24(3):5–51
- Gigerenzer G (2008a) Why heuristics work. *Perspect Psychol Sci* 3(1):20–29
- Gigerenzer G (2008b) *Gut feelings: the intelligence of the unconscious*. Penguin Books, London
- Gigerenzer G (2010) Moral satisficing: Rethinking moral behavior as bounded rationality. *Top Cogn Sci* 2(3):528–554
- Gigerenzer G, Kurzbanhauser S (2005) Fast and frugal heuristics in medical decision making. In: Bibace R, Laird JD, Noller KL, Valsiner J (eds) *Science and medicine in dialogue: thinking through particulars and universals*. Praeger, Westport, pp 3–15
- Gigerenzer G, Todd PM (1999) *Simple heuristics that make us smart*. Oxford University Press, Oxford
- Glockner A, Betsch T (2008) Multiple-reason decision-making based on automatic processing. *J Exp Psychol Learn Mem Cogn* 34(5):1055–1075
- Gonsen R (1998) *Biotechnology: a characterisation of the technology and implications for developing countries*. Technological capabilities in developing countries. Palgrave Macmillan, London, pp 41–69
- Gorod A, Nguyen T, Hallo L (2017) Systems engineering decision-making: optimizing and/or satisficing? In: Annual IEEE international systems conference (SysCon), Montreal, QC
- Gray B (2009) Review of acquisition for the secretary of state for Defence. HMSO, London
- Hartley K (1998) Defence procurement in the UK. *Def Peace Econ* 9(1–2):39–61
- Hobday M (1998) Product complexity, innovation and industrial organisation. *Res Policy* 26(6):689–710
- Johnson WM, Johnson CO (2002) The promise and perils of spiral acquisition: a practical approach to evolutionary acquisition. *Acquis Rev Q* 9(3):175–189
- Karnad B (2017a) Litigating Tejas LCA's quality and utility, Security Wise, November 22, 2017. <https://bharatkarnad.com/2017/11/22/litigating-tejas-lcas-quality-utility/>. Accessed 7 Aug 2019
- Karnad B (2017b) The tragedy of Tejas. In: *The open magazine*, February 15, 2017. <https://openthemagazine.com/features/national-security/the-tragedy-of-tejas/>. Accessed 28 July 2019
- Katz J (1984) Domestic technological innovation and dynamic comparative advantage. *J Dev Econ* 16:13–37
- Kausal T (1999) *A comparison of the defense acquisition systems of France, Great Britain*. DIANE Publishing, Berlin
- Kelman M (2011) *The heuristics debate*. Oxford University Press, Oxford
- Kheirandish R, Mousavi S (2018) Herbert Simon, innovation, and heuristics. *Mind Soc* 17(1–2):97–109
- Klein (2002) *Optimising fiction*. In: Gigerenzer G, Selten R (eds) *Bounded rationality: the adaptive toolbox*. MIT Press, Cambridge
- Lall S (1987) *Learning to industrialize: the acquisition of technological capability by India*. Springer, Berlin
- Lall S (1992) Technological capabilities and industrialization. *World Dev* 20(2):165–186
- Latham A, Hooper N (eds) (2013) *The future of the defence firm: new challenges, new directions*, vol 79. Springer, Berlin

- Lember V, Kattel R, Kalvet T (eds) (2014) *Public procurement, innovation and policy: International perspectives*. Springer, Berlin
- Lorell MA, Graser JC (2001) An overview of acquisition reform cost savings estimates. RAND Corporation, Santa Monica
- Lorell MA, Lowell J, Younossi O (2006) Evolutionary acquisition: implementation challenges for defense space programs, vol 431. Rand Corporation, Santa Monica
- Markowski S, Hall P (1998) Challenges of defence procurement. *Def Peace Econ* 9(1–2):3–37
- Mousavi S (2018) What do heuristics have to do with policymaking? *J Behav Econ Policy* 2(1):69–74
- Nelson RR (2008) Economic development from the perspective of evolutionary economic theory. *Oxf Dev Stud* 36(1):9–21
- Nelson RR, Winter SG (1982) *An evolutionary theory of economic change*. Belknap Press, New York, pp 929–964
- Park TY (2012) How a latecomer succeeded in a complex product system industry: three case studies in the Korean telecommunication systems. *Ind Corp Change* 22(2):363–396
- Persson A, Ryals L (2014) Making customer relationship decisions: analytics v rules of thumb. *J Bus Res* 67(8):1725–1732
- Pickup SL, Lentini P, Cameron M, Jones M, Langley S, Lipton A, Ullengren M (2010) Unmanned aircraft systems: comprehensive planning and a results-oriented training strategy are needed to support growing inventories (No. GAO-10-331). Government Accountability Office, Washington DC
- Prencipe A (2000) Breadth and depth of technological capabilities in CoPS: the case of the aircraft engine control system. *Res Policy* 29(7–8):895–911
- Ray AS, Bhaduri S (2001) R&D and technological learning in Indian industry: econometric estimation of the research production function. *Oxf Dev Stud* 29(2):155–171
- Read D, Grushka-Cockayne Y (2011) The similarity heuristic. *J Behav Decis Mak* 24(1):23–46
- Rich M, Dews E, Batten Jr CL (1986) Improving the military acquisition process: lessons from RAND research (No. RAND/R-3373-AF/RC). Rand Corp., Santa Monica
- Rogerson WP (1995) Incentive models of the defense procurement process. *Handb Def Econ* 1:309–346
- Rosenberg N (1976) *Perspectives on technology*. CUP Archive, Cambridge
- Salmon J (2015) Satisficing 2 (squared) in system of systems engineering design. In: 2015 Annual IEEE systems conference (SysCon) proceedings. Institute of Electrical and Electronics Engineers, pp 332–334
- Sceral M, Erkoyuncu JA, Shehab E (2018) Identifying information asymmetry challenges in the defence sector. *Proc Manuf* 19:127–134
- Scherer FM (1964) *The weapons acquisition process: economic incentives*. Division of Research, Graduate School of Business Administration, Harvard University, Cambridge
- Schwartz M (2014) *Defense acquisition reform: background, analysis, and issues for congress*. Library of Congress Washington DC, Congressional Research Service, Washington
- Shukla A (2009) Army warms up to indigenous Akash missile, *Business Standard*, November 07, 2009. [https://www.business-standard.com/article/economy-policy/army-warms-up-to-akash-missile-109110700042\\_1.html](https://www.business-standard.com/article/economy-policy/army-warms-up-to-akash-missile-109110700042_1.html). Accessed 15 Aug 2019
- Shukla A (2016) Taking Tejas forward. *Business Standard*, July 5, 2016. [https://www.business-standard.com/article/opinion/ajai-shukla-taking-tejas-forward-116070401158\\_1.html](https://www.business-standard.com/article/opinion/ajai-shukla-taking-tejas-forward-116070401158_1.html). Accessed 11 Oct 2019
- Simon H (1956) Rational choice and the structure of the environment. *Psychol Rev* 63(2):129–138
- Simon HA (1967) Motivational and emotional controls of cognition. *Psychol Rev* 74(1):29–39
- Simon HA (1972) Theories of bounded rationality. *Decis Organ* 1(1):161–176
- Smith DJ, Tranfield D (2005) Talented suppliers? Strategic change and innovation in the UK aerospace industry. *R&D Manag* 35(1):37–49
- Snowden DJ, Boone ME (2007) A leader's framework for decision making. *Harvard Bus Rev* 85(11):68–76
- Subramanian TS (2012) Radar power. *Frontline* 29(3). <https://frontline.thehindu.com/static/html/fl2903/stories/20120224290309800.htm>. Accessed 25 July
- Sylvester RK, Ferrara JA (2003) Conflict and ambiguity implementing evolutionary acquisition: lessons Learned. *Acquis Rev Q* 10(1):3–29
- Thiagarajan S (2017) Why building more Tejas fighters is a superior option for the Indian air force. *Delhi Defence Review*, December 11, 2017. <http://delhifencereview.com/2017/12/11/why-building-more-tejas-aircraft-is-a-superior-option-for-the-indian-air-force/>. Accessed 18 Aug 2019
- Tian N, Fleurant A, Kuimova A, Wezeman PD, Wezeman ST (2018) *Trends in world military expenditure, 2017*. Stockholm International Peace Research Institute, Stockholm



- Wellman GL (2003) A Delphi expert assessment of proactive contracting in an evolutionary acquisition environment. Wright-Patterson Air Force Base, Ohio, Air Force Institute of Technology, AFIT/GAQ/ENV/03-09
- Witt U (2003) Economic policy making in evolutionary perspective. *J Evolut Econ* 13(2):77–94
- Wylie R, Markowski S, Hall P (2006) Big science, small country and the challenges of defence system development: an Australian case study. *Def Peace Econ* 17(3):257–272

**Publisher's Note** Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.