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Review of the modelling approaches for Availability Contracts in the military context.

Duarte Rodrigues[a], John Erkoyuncu[a], Andrew Starr[a], Steve Wilding[b], Alan Dibble[b], Martin Laity[b]

[a]Cranfield University, Cranfield, Bedfordshire, MK43 0AL, United Kingdon

[b]Babcock, United Kingdom based

{d.rodrigues@cranfield.ac.uk; j.a.erkoyuncu@cranfield.ac.uk; a.starr@cranfield.ac.uk; steve.wilding@babcockinternational.com; alan.dibble@babcockinternational.com; martin.laity@babcockinternational.com}

Abstract

The defence context more recently has been experiencing a significant shift towards servitization. As competition has increased, commercial strategies are increasingly moving towards providing through-life solutions for complex engineering products such as submarines. Within such a context value for money is an essential driver in a life cycle sense for selecting a bid. The defence sector has largely been affected by this change in the business environment. Industrial Product Service System (IPS^2) is a model of providing services that satisfy industrial customers and aims to reduce lifecycle impacts of products and services through product servicing, remanufacturing and recycling. This approach has proved to be an effective solution to enhance the services support in military projects. IPS^2 offers client value by responding more efficiently to the client demands with reduced prices; it is delivered in the form of contracting approaches between Ministry of Defence (MoD) and industry; these contracts can differ in several aspects as risk sharing, application level, ownership policy and supportability specifications vary. This research focuses on Contracting for Availability (CfA), which is a particular approach of IPS^2. The paper aims to present the review of literature in designing support strategies for CfA, identifying the good practices and challenges, and to propose a systematic approach to fill the industrial and academic gap towards an optimization of the current modelling process. This work starts by presenting a literature review in IPS^2; it then moves into the optimization processes, describing how contractors currently design a long term service support contract in the military context with better value for money and high level of system readiness. The key cost and performance drivers are identified and a framework is presented to enhance the design process of CfA. The methodology of the paper relies on literature. This research aims to extend the work of several authors in predicting the cost of services in the military contracts.

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1. Introduction

Over the recent decades, competition among the manufacturing sectors has raised and companies are forced to change their commercial strategies in order to keep competitive. Products that were traditionally sold purely as a physical good started to be sold as a package which includes the physical product together with services to support that product through its entered life-cycle. Services are less likely to be seen as an "add-on" to the product [1] and are increasingly considered as a "customer benefit package" [2] that extends the life of the product and reduces its life cycle costs. The term *service* refers to any support system such as: actions on hardware (remanufacturing, spares provision, on-site work); decision-making and forecasting; operations planning; data collection storage; or intellectual property (education of users and suppliers) [3]. The addition of a service to a product offering is called

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servitization [4] and its integration into the product offerings has been increasing in terms of applicability, responsibility and complexity.

The growth in servitization can be found in a wide range of applications, especially in the military context under the role of Contracts for Availability (CfA), a particular case of Industrial Product Service System (IPS^2). CfA are usually long term fixed price contracts agreed between Ministry of Defence (MoD) and industry which aim to sustain the availability of the system at an agreed level of readiness [5]. The term 'industry' covers both prime contractor, (which is the legal entity whom MoD require to deliver a product, e.g. a fully functioning ship, or service [6]), and supply chain. MoD has found several advantages in this contracting approach as it can offer savings and sharing of project risks with industry, which takes on the responsibility to deliver agreed level of equipment and services availability for a fixed price. Moreover, as the contractor shares the business risk with MoD, it is in their own interest to get familiar with the military activities, to see what technologies are being used and what kind of services and equipment upgrades would fit the military needs [3] and consequently, it represents increased value to MoD: "industry will be motivated to invest its own resources, alongside our research (MoD' research), to help us understand the opportunities and offer unsolicited proposals for improving our capability" [6]. However, this partnership between MoD and industry requires a good alignment between the parts in order to facilitate the information sharing and to build the better collaboration strategy; it also assists the contractor to understand the operational context and the Defence Lines of Development (DLoDs). The DLoDs involve a combination of processes, information, equipment and people that underpin the military structure and need to be considered at the time of designing any service to support the military capability. Furthermore, modelling the DLoDs provides a major challenge but also a big opportunity for improvements towards enhancing the current process of designing strategies for the bidding stage of CfA. This paper looks at reviewing the literature related to the DLoDs and propose a research methodology approach towards optimizing the CfA design strategies, with a special focus on the trade-off analysis across DLoDs.

1.1. Contracts for Availability

Under a CfA agreement industry is required to deliver outcomes defined in terms of availability. That means MoD pays for availability (use of equipment) not specifically repairs [7]. MoD defines CfA as a commercial process which seeks to sustain a system or capability at an agreed level of readiness, over a period of time, by industry [8]. Readiness is the term used to describe the means by which MoD holds its military forces at varying levels of preparedness to respond to emerging operations [9]. Initially defined in terms of platform (ship, aircraft, vehicle, etc..) availability has evolved into outcomes more clearly linked to the MoD's operations [10]; they are now applied to Systems (Including Radars, IFF, power packs, armaments and simulators), Sub Systems (Such as engines and guns), and Equipment (Including small arms, mobile generators and radios) [5]. The "systems" at each level are seen as "sub systems" from the level above [11]. Without losing generality this work will follow the definition of equipment given by MoD in the Acquisition Operating framework: "equipment refers to the provision of military platforms, systems and weapons, (expendable and non-expendable, including updates to legacy systems) needed to outfit/equip an individual, group or organisation"; consequently the word "equipment" will refer to either system, sub system, or small equipment.

A typical example of a CfA is the supply of aircraft engines, in which the customer pays only for the use of the engine and does not purchase the hardware [3].

1.2. Through Life Perspective of CfA

CfA are normally long term contracts that can last in some cases over 20 years [3]. Therefore, it is necessary to correctly define the categorization of the contract life cycle stages in order to employ the best strategies according to each project phase specifications. MoD identifies 6 main phases in the CfA life-cycle: Concept, Assessment, Demonstration, Manufacture, In-service and Disposal (CADMID). MoD also refers to two major contractual approval points: the Initial Gate at the end of the concept phase and the Main Gate at the end of the assessment phase [12], as represented in the figure below:

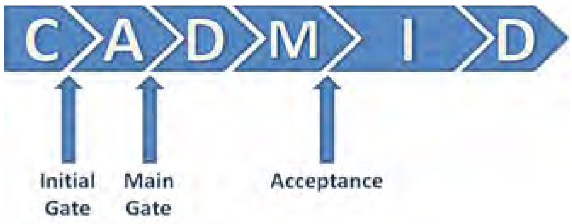

Fig. 1 CADMID Cycle [13]

1.3. Modelling

Modelling a system is the process of representing that system in a simpler way, which has the purpose of enabling the analysis to predict the effect of changes to the system [14]. In the service system context, modelling has a very important role as it aims to represent the development of the services. However, due to the complexity of the services, the difficulty in accurately describing human behavior, and the amount of resources required to deliver services, modelling services is a difficult task and very time-consuming which may explains why it has received little attention over the years [3].

There are several different approaches for modelling service systems; Shostack [15] developed the service blue print approach which attempts to map a system for visualization, enabling services to be given proper position and weight in the market entity context. Later on, Lovelock [16] highlighted that service blueprints are prone to fail if they are not built based on a good alignment between costumer and services provider; indeed, he proposed to produce two blueprints: one from the company's perspective and other from the costumer's perspective, for further consensus. The blue print approach requires a graphical language to assist the process. The Structured Analysis & Design Technique (SADT) is a graphic process modelling language developed by D. T. Ross of SofTech Inc, which consists of a set of interrelated diagrams that collectively describe a system; the basic module of the technique is a process box denoting an activity, which has inputs, outputs, activity controls, and mechanisms. SADT has a static modelling paradigm that can deal with the representation of the structure of a system but cannot deal with the system behavior over time, although it can help in the preparation for simulation [3]. Simulation is the operation of a model that evaluates the performance of the system, by testing different configurations of interest and over long periods of real time [14].

A subset of the SADT technique was adopted by the US Air Force in the integrated computer-aided manufacturing project, renamed IDEF0 and placed in the public domain [17]. In [18] the authors proposed an extension of the IDEF0 modelling to act as a process reliability assessment tool and show how to apply this approach to high level projects management frameworks as for example PRINCE2.

Another interesting and innovative modelling approach applied to stochastic and non-deterministic contracts is proposed by Delahaye et al. [19]. The authors use a mathematical language formalism to describe the contract system. They map aspects as contract, assumptions, and availability into a mathematical alphabet in order to model a system over time and schedule the most suitable activities according to the desired project outcomes. In the Applied Reliability and Maintainability Manual for Defence Systems [5] the authors provide an overview of the current elements and concepts involved in the modelling process, covering different modelling approaches and techniques enriched with a case study analysis in modeling the reliability and performance of a network communication systems.

1.3.1. Literature review of the modelling practices for design CfA

CfA can be applied to a wide range of military capabilities such as platforms, systems, subsystems, equipment, spares, personnel, services, or facilities [5]. Each different type of application may incur in some design details variations. A structured research among literature was done aiming to find the current modelling approaches applied to design CfA. This research aims to present one generic sequence of steps that seems to be unanimously adopted in all of the CfA types, at the early stages of the contracts design:

- Collect data from the process (either historical data or expert opinions);
- Specify the modelling structure to the system attributes (e.g., physical representation model, neural networks, diagrams, tables, abstract models);
- Build the assumptions list;
- Select a numerical technique to find correlations between the parameters of the system;
- Integrate risk and uncertainty analysis;
- Perform a sensitive analysis of the model results in order to find drivers for improvement;
- Validate the model against an 'unseen' data set or user appreciation.

In the first phase of the modelling process, the task requirements and the resources required to deliver those tasks are listed; the customer affordability issues are considered and the assumptions list is built. The service breakdown structure is then performed and the risk drivers for cost and availability are identified (e.g. price and equipment usage variance, manpower requirements, mean time to repair, etc…). The relationships between the risk drivers are then built and the expected monetary value of each risk driver is placed. The relationship plan with the supplier is also established as it has an important impact on the price and availability of supplies. The above factors are all inputs to the model [20].

After collecting all the inputs and identifying the risk drivers, contract designers look at addressing the recurrent uncertainties for each risk driver [21]. The uncertainty associated to a performance driver can be expressed using either a single or three point-estimate techniques [22].

The last phase of the modelling process consists in evaluate all the previous elements into a final model in order to design the desired support strategy plan and estimate the associated cost. The modelling techniques can vary depending on the amount of information available [22]. When the level of data available is low, the modelling process is based on expert opinions or can be also based on analogy; the project designers associate their knowledge experience with comparisons to previous similar projects to build estimates and solutions for the current project. When the level of information available is high, parametric techniques (also known as top-down applications) such as regression analysis, fuzzy logic, or neural networks [1; 21], and simulation tools are applied to model the data. Also bottom up technique or mixed-approach can be applied [20]. Nonetheless, expert opinion and analogy techniques are always applied to validate and enhance the accuracy of the final model results. Next table illustrates the modelling techniques more suitable to be applied according to the level of information available, at the design stage of CfA:

Table 1 - Modelling approaches for CfA (adapted from [20])

Design Stage		Level of information available		
		Low	Medium	High
Type of Availability Contract	More Use-Oriented	.Joint cost modelling .Expert opinion	.Joint cost modelling .Expert opinion .Bottom-up	.Joint cost modelling .Expert opinion .Bottom-up .Simulation
	More Result-Oriented	.Joint cost modelling .Expert opinion	Joint cost modelling .Expert opinion .Analogy .Performance - based methods .What-if analysis .Parametric	.Joint cost modelling .Expert opinion .Combined top-down and bottom-up methods .Simulation .Performance-based method

Due the dynamic nature of CfA, simulation tools are an efficient approach to model these type of contracts when sufficient information is provided. There are several well recognized simulation techniques in literature including: Monte Carlo simulation, Discrete Event simulation, System Dynamics, and Agent Based simulation. Typical examples of simulation tools are: @RISK [23], Crystal Ball [24], or ModelRisk [25].

1.4. DLoDs

The DLoDs provide a way of view a programme, set of programmes or strategy from a MoD perspective. In a sense it provides a means for the MoD for matrix management of a programme or strategy [26]. UK MoD DLoDs are normally referenced by the acronym ''Tepid oil'' and they cover: **T**raining, **E**quipment, **P**ersonnel, **I**nformation, **D**octrine & Concepts, **O**rganisation, **I**nfrastructure, **L**ogistics, and **I**nteroperability (as an overarching theme) [6]. The definition of each DLoD according to the Acquisition Operating Framework (AOF) is described below:

<u>Training</u>: The provision of the means to practise, develop and validate, within constraints, the practical application of a common military doctrine to deliver a military capability.

<u>Equipment</u>: The provision of military platforms, systems and weapons, (expendable and non-expendable, including updates to legacy systems) needed to outfit/equip an individual, group or organisation.

<u>Personnel</u>: The timely provision of sufficient, capable and motivated personnel to deliver Defence outputs, now and in the future.

<u>Information</u>: The provision of a coherent development of data, information and knowledge requirements for capabilities and all processes designed to gather and handle data, information and knowledge. Data is defined as raw facts, without inherent meaning, used by humans and systems. Information is defined as data placed in context. Knowledge is Information applied to a particular situation.

<u>Doctrine & Concepts</u>: Doctrine is an expression of the principles by which military forces guide their actions and is a codification of how activity is conducted today. It is authoritative, but requires judgement in application. A Concept is an expression of the capabilities that are likely to be used to accomplish an activity in the future.

<u>Organisation</u>: Relates to the operational and non-operational organisational relationships of people. It typically includes military force structures, MoD civilian organisational structures and Defence contractors providing support.

<u>Infrastructure</u>: The acquisition, development, management and disposal of all fixed, permanent buildings and structures, land, utilities and facility management services (both Hard and Soft facility management (FM)) in support of Defence capabilities. It includes estate development and structures that support military and civilian personnel.

<u>Logistics</u>: Logistics is the science of planning and carrying out the operational movement and maintenance of forces. In its most comprehensive sense, it relates to the aspects of military operations which deal with; the design and development, acquisition, storage, transport, distribution, maintenance, evacuation and disposition of materiel; the transport of personnel; the acquisition, construction, maintenance, operation, and disposition of facilities; the acquisition or furnishing of services, medical and health service support.

<u>Interoperability</u>: In addition to the DLoDs, Interoperability is included as an overarching theme that must be considered when any DLoD is being addressed. The ability of UK forces and, when appropriate, forces of partner and other nations to train, exercise and operate effectively together in the execution of assigned missions and tasks. In the context of DLoDs, interoperability also covers interaction between services, UK Defence capabilities, other Government departments and the civil aspects of interoperability, including compatibility with civil regulations. Interoperability is used in the literal sense and is not a compromise lying somewhere between integration and de-confliction.

Although DLoDs are a UK construct, other nations defence department have equivalent capability development guidelines, as such:

- The Australian Fundamental Inputs to Capability (FIC): Organisation, Personnel, Collective training, Major systems, Supplies, Facilities, Support, can Command & management;
- The Canadian Capability Inputs: Personnel, R&D/Ops research, Infrastructure & Organisation, Concepts, doctrine & collective training, IT Infrastructure, and Equipment, supplies & services;
- The USA Capability Inputs: Doctrine, Organisation, Training & education, Material, Leadership, and People.

In UK, DLoDs must be the guidance for any military support activity as they provide a useful summary of the range of factors that must be considered when making decisions on capability and force structure. Indeed, industry has already been suggested as a line of development because of its role in supporting DLoD for a particular capability and the alignment/relationship between supplier and customer in developing the DLoD [27]. Moreover each DLoD can be broken down into several attributes, e.g. 'Training' can be broken down into: Train the Maintainers, Training Needs Analysis (TNAs), Individual Conversion Training (In-Theatre), Individual Conversion Training (Pre-Deployment) and Collective Training [28].

Aiming to ascertain the current understanding about the DLoDs, it was made a structured bibliographic research among studies related to the DLoDs, not only in the military context but also in other relevant industries such as aircraft and health. The next table illustrates the literature maturity level related to each DLoD among different industries:

Table 2. DLoDs literature assessment

DLoD	Industry	**Literature Maturity Level** (nº of papers found): -**High**: 20 or more -**Medium**: [10-20[-**Low**: [5-10[-**Lack of research**: [0,5[
Training	Military	Medium
	Food	Medium
	Health	Medium
	Aircraft	Medium
	Hotel	Medium
	Overall	High
Personnel	Military	High
	Health	Medium
	Overall	High
Organisation	Military	Low
	Healthy	Low
	Overall	Low
Logistics	Military	High
	Overall	High
Infrastructure	Military	Low
	Overall	Low
Information	Overall	Medium
Equipment	Military	High
	Health	Medium
	Overall	High
Concepts and Doctrine	Military	Medium
	Health	Medium
	General	Medium
Interoperability	Military	Medium
	General	Medium
All DLoDs trade-off analysis	General	Low

1.4.1. DLoDs Trade-off

Trade-off is a structured evaluation and comparison of a range of potential solutions against defined objectives and constraints; it aims to deliver a cost effective solution to one or more capability gaps by seeking opportunities to optimise the performance, cost and time characteristics of a project or programme. Based on the studies found in literature related to the DLoDs, it was possible to identify some of the most important attributes of each DLoD as well as to build some qualitative links between those attributes. Some of those studies are presented in this section.

In [29] the author conducted a research in the food industry where he concluded that access to training is positively related to organisational commitment; employees' perceived degree of support for training and perceived degree of benefits from training positively affects their commitment. He also stated that organisational commitment has a positive relationship with customer service quality and mediates the relationship between perceived accessibility to training, perceived support for training, and perceived benefits from training with service quality.

Rolande Paris in [30] looked at how an international military action can avoid mass atrocities by assessing the link between external military action and the desired outcome of preventing or stopping mass killing. He reported that there is very little and transparent information about how UK military forces project and deliver their preventive humanitarian interventions; as a consequence they start to lose people's trust which harms the future of the responsibility to protect.

In [31] the author described the role of communication on learning organisations (trust, commitment, perceived organisational support), and the indicators needed for preparing for this state (organisation-employee relationship, valuing the employee, employee empowerment, and employee ownership and acceptance of responsibility).

Grant in [32] agreed that personnel well-being level is positively led by employees' perception of pleasure invoking either negative or positive thoughts or feelings, and employees' perceptions of whether they have reached their potential.

Hill [33] looked at the positive impact that good nutrition has on military personnel body composition, physical fitness and operational capability.

However it was possible to find several studies related to each DLoD, there are several points to highlight:

- There is a trend for literature to focus more on Training, Logistics, Personnel, and Equipment DLoDs; it suggests that there is a lack of understanding in the other DLoDs; moreover, most of the studies found in this research are not related to the military context, so they need to be validated with military data to be applied to this context;
- Although the literature findings help to breakdown each DLoD and to find relationships between its attributes, these attributes can vary depending of the industry context so they need to be adapted and validated to the military context;
- The relationships between DLoDs and respective attributes are mainly qualitative and there are no quantitative measurement in how much each attribute influence other attributes; also there is no guidance in how much each DLoD influences the cost and availability of resources in any context;

In summary there is a general lack of research in assessing the DLoDs especially in the military context. The literature available is very limited and needs to be developed and expanded.

2. Conclusion and future research

CfA is the major contracting practice adopted by UK MoD and also by other defence authorities such as the American DoD [34]. Therefore, there is an increasing amount of interest from MoD and industry to optimize these contracting arrangements.

Designing a good CfA support strategy requires an understanding of how to estimate the cost of military services, which is a challenge [20; 35]; CfA designing teams need to improve their current understanding about the key contract performance drivers, in particular: contract duration, project risks and DLoDs. They need to put the suitable amount of effort into these drivers to ensure that projects run according to the contractual expectations and to ensure their profitability. Furthermore, there are no tools that accurately assess and design CfA, dealing with all the risks and uncertainties involved. Also, DLoDs are challenged by a general lack of understanding. Most of the current CfA design teams concentrate their effort on training and equipment DLoDs and their estimates are mostly based on expert opinion and historical data, which can be unreliable. In addition, the absence or incomprehensibility of historical data is major source of challenge [35], which causes further reliance on expert opinion. Literature is encouraging for identifying new opportunities to improve the understanding of how to better model the DLoDs. In [36] the authors discuss breaking down some DLoDs and propose a model that assesses the impact of different allocation of DLoDs resources on the military capability of force elements and budget. This model may be a very good approach to be applied on the in-service phase of CfA and a potential extension, adaptation and improvement may be developed to be applied on designing CfA support strategies.

By identifying the current literature gap in assessing the DLoDs, this paper aims to be a motivation and guidance for further research in modelling techniques that can be applied to this context and enhance the current practices.

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