



Mapping a product-service-system delivering defence avionics availability



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ARTICLE INFO

Keywords:

Product service system
Case study
Avionics
Availability
Defence
Conceptual model

ABSTRACT

Long-term support agreements such as availability-based contracts are often associated with the servitization of business models in such sectors as defence aerospace. In practice, there is no unambiguous way of linking availability and service outcomes from an operational perspective; rather, the focus tends to be placed almost exclusively on product-related metrics. To address this gap, this paper outlines a conceptual model of how advanced service outcomes should be delivered under an availability-based contract for defence avionics. The model is grounded on empirical evidence gathered through an in-depth case study in the UK defence sector. The research is one of the first attempts to shift the focus away from a notion of availability as a property designed into a piece of equipment, and to detect its emergence from the interactions between relevant socio-technical elements within the underpinning advanced service delivery system, or Product-Service-System (PSS), identified by analysis of empirical data. This research provides insights into where action should be taken within a PSS that would be difficult to obtain from the analysis of field reliability data alone. It also provides a conceptual model that can assist the formulation of scientific models based on quantitative data such as multi-echelon inventory systems for repairable items. While the transferability of the findings is limited by the specificity of the case, a detailed description is provided to facilitate comparison with other cases.

1. Introduction

Over the past decades defence industrial supply systems across Europe and US have changed from having a pyramid structure with discrete tiers to interdependent supplier networks. The forces driving this transformation include an increase in outsourcing and a decrease in the number of adversarial buyer-seller relationships adopted as part of governments' procurement processes; a reduction in manufacturing capability across the defence industry supply base; and the increasingly transnational nature of equipment development and production projects (Dowdall, 2004). Former upper tiers are now incentivised to take responsibility for how their products perform in the field rather than 'on the whiteboard'. For example, following the 2013 spending review the UK Ministry of Defence (MoD) shared with industry the challenge of reducing the cost of warship repair, maintenance and dockyard operations by signing innovative in-service support contracts worth £3.2Bn with BAE Systems and Babcock (MoD, 2015).

Availability-based contracts are incentivised contractual mechanisms that challenge an incumbent business model in such fields as

defence aerospace, where an asset (an aircraft, an aircraft engine, etc.) that fails to deliver its functionalities in the field is the source of additional streams of revenue through aftersales support (Caldwell and Settle, 2011). Examples include a recent £112 m extension of the availability-based in-service support contract for the UK Royal Air Force's (RAF) Eurofighter Typhoon fleet (BAE Systems, 2015), and a £420 m amendment to the Chinook through-life support contract to cover in-service support for the next five years while ensuring high levels of availability (MoD, 2015).

The concept of availability as an objectively observable indicator was originally developed in the field of reliability engineering and is implicitly adopted for the formulation and execution of availability-based contracts (Kashani Pour et al., 2016). For example, in outlining a business case for avionics prognostic health monitoring equipment Jazouli and Sandborn (2010) define availability as: "... the probability that a [technical] system will be able to function when called upon to do so." Although the specific analytical expression of availability may vary it is commonly understood that such features as reliability and maintainability are designed into individual technical systems and

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must act as the point of focus for the analysis. This analytical approach typically identifies causal links between availability growth and interventions in technical systems such as design reviews. While reviewing the design of a technical system may improve reliability under test-rig conditions it does not guarantee *per se* that the number of support interventions demanded on average by an item in the field will decrease. For example, extensive analysis of field reliability data obtained from a defence avionics case demonstrates that a multi-organisation logistic support system involved in the execution of an availability contract was facing, on average, a growing number of interventions per item despite an improved product design (Settanni et al., 2015). Evidence therefore suggests that the traditional view of availability as a property designed into a technical system should be complemented by an exploration of how the organisations that operate along the support chain contribute or fail to contribute to a diversity of capabilities to achieve the shared objective of maintaining a technical system in an operable and committable state (Hollick, 2009).

Shifting the focus away from purely technical systems, Baines and Lightfoot (2013) suggest that availability is a type of *advanced service*, and that the system of operations by which such a service is provided, called Product Service Systems (PSS), is as important as the service offering itself. This challenging view of availability as a service output of a PSS imposes a distinction between retrospectively computing an availability indicator which determines, based on its interpretation, whether contractually agreed levels of performance are delivered or not, and proactively providing an advanced service. Regardless of the service outcome it delivers, a PSS typically encompasses both technical and social elements (Morelli, 2002; Meier et al., 2010a). The technical elements of a PSS are regarded as a means to achieve ends rather than as the point of focus of the analysis (Settanni et al., 2014). In practice, investigating the system which delivers an innovative availability-based support solution rather than the asset being supported can be a challenge (Kapletia and Probert, 2010; Ng et al., 2011). The importance of achieving operational alignment across multiple organisations to successfully deliver under an availability-based contract may be disregarded even by the parties involved (Ng et al., 2013). Greater attention is paid to the design and theoretical refinement of contractual mechanisms (Selviaridis and Wynstra, 2015).

Following calls for more empirical research on PSS modelling (e.g. Cavalieri and Pezzotta, 2012), this paper assesses the performance of a PSS under an availability-based contract using a case based approach on a real-world industrial setting. It shows that it is a complex process requiring detailed exploration and analysis, which cannot be adequately captured by quantitative data alone. The analysis of a conjunction of causal mechanisms in the production of a given outcome is recognised in the organisation-orientated literature (e.g. Mills et al., 2013; Ng et al., 2011; Perrow, 1984). The novelty of the research presented in this paper lies in the identification through empirical evidence of causal conjunctures that complement product-related quantitative data and the visualization of this evidence through mapping techniques to support the underlying narrative of what the delivery of availability as an advanced service 'looks like' in a real-world case. These two activities taken together form an overall act of appreciation which qualifies as *conceptual modelling* (Sagasti and Mitroff, 1973; Becker et al., 2010). A conceptual model structures and delimits the areas of concern for the analyst with regards to a problem situation in a defensible way (Wilson, 2001). Although seldom made explicit and formalised, conceptual models deeply affect how scientific models are formulated, solved, implemented and validated (Sagasti and Mitroff, 1973). For example, the through-life costing methodology described by Settanni et al. (2014) explicitly requires a conceptual model of the PSS to derive a blueprint for the attribution of costs to multiple service outcomes. Hence, not only does a defensible conceptual model provide insights in its own right, but also it is a valuable premise for mathematical modelling. The conceptual model outlined in this paper is a complement, not an alternative to the

assessment of availability from quantitative data about technical systems, since it explores *how* the delivery of availability as an advanced service is realised in an industrial setting.

The following research questions are addressed:

- 1) *How* is availability delivered as an advanced service outcome under an availability-based contract in an actual industrial context?
- 2) Which aspects of the delivery of such an advanced service can be represented?

In order to provide focus in terms of an approach to investigate the outcomes of systems that are socio-technical in nature, preference is accorded to insights from the literature on accident investigation as well as on availability-based contracts and PSS modelling. Empirical evidence is gathered through an in-depth case study on avionics support under an availability-based contract in the UK defence sector. A conceptual model of the PSS of interest is then outlined through the analysis of the qualitative data obtained.

The rest of this paper is structured as follows. Section 2 summarises the literature on current approaches to investigate and represent PSS with a focus on the business model introduced by availability-based contracting. In Section 3 the research approach is presented and the case study setting is outlined. Findings from the case study are presented in Section 4, and their implications are discussed in Section 5. The paper closes highlighting limitations of the proposed approach and further work needed.

2. Literature overview

Availability-based contracts are specific forms of a broader category known as performance-based contracts (PBC). Providing a state-of-the-art in PBC research is outside the scope of this research, and is dealt with elsewhere (Selviaridis and Wynstra, 2015). Availability-based contracts are typically associated with the servitization of business models in sectors such as defence aerospace. For example, making reference to ATTAC (Availability Transformation: Tornado Aircraft Contract) a 'complex engineering service system' conveys the concept that value is created 'in-use' through the interaction of processes, people, technology and assets under availability based contracts (Ng et al., 2011).

From an operational perspective there is no unambiguous way of linking 'availability' and 'service outcome'. For example, in a servitized business model the cost of providing a service is often understood to be the expenditures incurred over the in-service phase of a durable product due to the occurrence of failure, as in traditional through-life costing models (Settanni et al., 2014). While some views on availability suggest a link with service outcomes they remain anchored in evidence gathered through product-related quantitative data only. Examples include Rijdsdijk (2013), who regards availability as a quality indicator which relates the performance of a product in fulfilling an intended purpose to its inherent ability to do so; Zio (2009), who introduces the concept of 'service availability' and highlights that availability is attained through the interaction of human, organisational and technical systems; and Houghton and Lea (2009), who report on the implementation of an availability-based contract for military vessels. Even works that conceptualise availability as an advanced service favour product-related metrics (e.g., Baines and Lightfoot, 2013).

Case study research on availability-based contracts has helped broaden the scope of the analysis beyond individual assets. However, such research is seldom concerned with outlining a formalised representation of a PSS that delivers availability as an advanced service. Mills et al. (2013) present a case study in defence aerospace and map the key actors involved in the execution of an availability contract through an Enterprise Image. Case studies are carried out in a similar context by Datta and Roy (2011) to outline a framework to support the implementation of an operations strategy, and by Kapletia

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