Cutting cost in service systems: Are you running with scissors?[1]

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One sentence summary:

A rigorous link between the domains of cost estimation, systems theory and accident investigation reveals fundamental epistemological limitations of commonly employed cost models when dealing with the characteristics of systems, particularly service systems, which may hinder the ability to take appropriate action for cost reductions.

Key points:

1. The ability to take action, in particular related to cost reductions in service systems, is strongly influenced by the understanding (epistemological assumptions) underlying a decision-support tool, in this case a cost estimate.
2. There is a conflict in the underlying epistemological assumptions about what is and can be known in such a socio-technical system as a service system.
3. A managerial perspective of cost estimation which neglects the essential characteristics of service systems may drive behaviour which is locally optimised but creates tension or failure at the system level.
4. Cost cutting decisions that are based on a flawed understanding of the situation can lead to counter-intuitive outcomes for organisations; hence practical guidance is needed to help managers consciously consider the underlying epistemological assumptions in a given situation.

1 Introduction

A desire for cost savings is often identified by key executives as leading customers to adopt services offered by organisations that have ‘servitized’ (Aston Business School, 2013). Yet, as identified in this article through a systemic theoretical insight, there are potentially disruptive mismatches between 1) the nature of the delivery systems underpinning the innovative service offering in companies that have servitized and 2) the methodological foundations of the approaches for the evaluation of the costs associated with these systems for decision making purposes. Statements such as “*Customers of servitization are reducing costs by up to 25-30%*” are based upon subjective judgments and many key questions are not addressed such as ‘which cost is meant?’, ‘how are costs determined?’ and ‘for what purpose was the cost computed?’. In the defence sector servitization frequently translates into contractual arrangements to guarantee asset-related performance, particularly asset availability. Claims related to the cost-effectiveness of these arrangements, which may eventually result in their practical implementation, are often made in the absence of sound business model analyses (GAO, 2008). In such cases as, for example, Pratt & Whitney’s F117 engines powering the US Air Force’s fleet of C-17A airlifters there has been a move back to transactional approaches to maintenance in the hope that more competition in the support contract bidding phase drives prices down (Trimble, 2013). However, it is acknowledged that in times of pressure on defence budgets apparently straightforward initiatives for saving money may prove ineffective since they compromise the ability to deliver capability when needed. For example, cuts in training and maintenance, reduction of force structure and cancellations of equipment programs which are already under way may eventually drive up an asset’s unit cost (Chinn, 2013).

In the public eye, cost tends to be addressed as something to fear and forecast (much as an adverse meteorological event), not something to understand and manage. This is particularly evident, for example, in the case of the F-35 Joint Strike Fighter (Coghlan, 2012, Fulghum *et al.*, 2011). Cost estimators and modellers in turn have long been concerned with predicting how much something costs using aggregate data and drawing on past experience of cost outturns, rarely asking why it will cost that much (Dean, 1993). This approach may give the impression that progress in understanding and controlling cost is being made despite the fact that the problem is only partially understood. The drawback in cost prediction for projects is typically a "fire fighting" approach to project problem resolution, resulting in a chance that, as and when the desired results are delivered, the asset is provided late and at a higher cost than planned (Burge, 2010).

This article suggests that the key to address these concerns is to build on a defensible conceptual representation of the socio-technical system underlying successful service delivery, as an integral part of the cost estimating process. This is demonstrated through a trans-disciplinary research approach, characterised by problem focus, evolving methodology and collaboration (Wickson, Carew & Russell, 2006). The problem at stake is that the methodological choices in costing advanced services, such as availability or other types of performance, delivered through a product-service-system may hinder rather than raise cost consciousness for informed decision making. A methodology to face such a problem has to respond to and reflect the specific problem and context under investigation. The development of such methodology, which is discussed in this paper, is through collaboration between authors having different expertise, and dialogue with industrial and institutional stakeholders.

The remainder of the paper discusses the characteristics of service systems, their associated costs and different perspectives on costs. A clarification of the links between action and understanding leads to the identification of an epistemological conflict in the perception of cost in service systems. It is concluded that epistemology is highly relevant for managerial decision making. Finally, future and on-going work is outlined.

2 Why service systems have their peculiarities

Manufacturers that have 'servitized' offer advanced services that are critical to their customers' core business processes through incentivised contracting mechanisms such as availability or performance-based contracts. For these providers servitization involves innovation of their internal capabilities in operations, and the service delivery system is just as important as the service offering itself (Baines & Lightfoot, 2013). This section provides theoretical insight into such a service delivery system from a 'system thinking' perspective, highlighting the aspects that may be a challenge for costing advanced services.

2.1 Seeing Service System as 'systems'

Advanced services are delivered by a "knowledge-intensive socio-technical system" sometimes referred to as Product Service System (Meier, Roy & Seliger, 2010; Baines & Lightfoot, 2013). A PSS being a particular case of system it exhibits common characteristics of systems (Blanchard, 2008, Wasson, 2006, Burge, 2010) , in particular:

a) It consists of multiple elements (or components),
b) Its elements are interacting with each other,
c) It has a purpose.

Also, a PSS is a special case of service systems. According to Wang *et al.* (2013) *service systems* exhibit distinguishing features such as a network infrastructure; a substance (the types of which include material, human/animal, energy and knowledge) flowing over such an infrastructure; and a protocol for the management (coordination, leading, planning and control) of both the structure and the substance.

Central to the concept of a service system is that it enables the customer to attain a result, or beneficial outcome, through a combination of activities and resources, including assets, to which both the service provider and the customer contribute (Ng *et al.*, 2011).

2.2 Service systems are socio-technical systems

Service systems are socio-technical systems due to the coexistence of physical and human components. This has long suggested that service system analysis should be approached as a social construction and that their technical representation should contain indications about potential functions, interaction between actors and functionalities and flows of events (Morelli, 2002).

Whilst methodologies like System Engineering aim at deriving possible solutions by applying techniques to a well-defined problem, a defensible intellectual process of thinking about a socio-technical system has to start by defining, not a problem but a situation that is problematic (Wilson, 2001). Dekker (2011) highlights the difficulty, when analysing a socio-technical system, of clearly identifying what is actually affected by an action and what is not. Hence, the boundaries between the "*system of interest*" (Wasson, 2006) and the exogenous components that affect or are affected by it (that is, the environment) should be determined by the purpose of the system description (what shall be examined and why), not by the system itself.

Drawing the system boundaries allows a distinction between what are deemed uncontrollable external events (originating with the environment) and controllable internal events. The former are the subject of "*forecasting*" whilst the latter are the subject of "*decision making*" (Makridakis, Wheelwright & Hyndman, 1998). In the context of 'servitization' the boundary defining lens is the *enterprise,* which "*imposes a holistic management or research perspective on a complex system of interconnected and interdependent activities undertaken by a diverse network of stakeholders for the achievement of a common significant purpose*" (Purchase *et al.*, 2011). However, only when all stakeholders involved share a common interest in taking action towards a common purpose – also by sharing financial information and insight of each other's processes (Romano & Formentini, 2012) – does the enterprise provide a reasonable scope for the analysis. An in-depth discussion of how to create potentially efficient governance relations within the enterprise in the presence of stakeholders with heterogeneous goals is beyond the scope of this paper. The interested reader is referred to (Tirole, 2001) for a theoretical baseline, and (Kim, Cohen & Netessine, 2007) for a specific discussion concerning availability-based contracts.

In socio-technical systems there is no reasonable prospect of gaining complete knowledge about the whole system (Hollnagel, 2012). Hence, local decision-making is always based on incomplete knowledge about the whole system and actions undertaken to optimally fulfil locally visible goals are prone to manifest in global system tensions or even failure (Snook, 2002, Dekker, 2011).

2.3 Service systems exhibit emergent properties

Importantly, it is not possible to deduce the properties and behaviour of the whole system from the properties and behaviour of its constituting elements in isolation (Burge, 2010). This has significant implications for the investigation of a system and its components as it excludes the possibility of capturing and superimposing individual components' characteristics to successfully describe the total system. Only when brought together and interacting with each other do emergent properties arise (Dekker, 2011, Burge, 2010). These may not even be predicable when looking at the complete system as their occurrence is based upon relationships between the components that may not be known, or knowable (Dekker, 2011). Some of these relationships may be intended or not, they may however only exist temporarily and can therefore be difficult or impossible to comprehend (Perrow, 1984). Hence, an understanding can only be acquired when the system is examined over time, and any investigation of a system can only provide a snapshot in time. In principle, this applies to cost as well – for example, through the concept of 'cost image' (Lindholm & Suomala, 2007).

2.4 Not all outcomes of a system are desired

There are multiple ways of approaching socio-technical systems. Bartolomei *et al.* (2012) provide an overview and framework. In the authors' opinions, however, the field of accident investigation provides insight into socio-technical systems that can be of particular interest for the analysis of service systems. Both domains are concerned with outcomes: accident investigation focuses on undesired outcomes in the form of accidents or incidents, where service systems deal with doing something 'right' from the customer viewpoint (hence delivering value in-use) or dealing with the consequences of failing to do so.

Two outstanding contributions in the field of accident investigation relate to large-scale multi-organisational delivery systems that produced highly undesired outcomes: "*The Challenger Launch Decision*" (Vaughan, 1997) deals with the explosion of the Challenger Space Shuttle shortly after lift-off in 1986. "*Friendly Fire*" (Snook, 2002) concerns the shooting down of two U.S. Army helicopters by two U.S. Air Force fighter jets in 1994. Both works were motivated by the lack of insight the preceding investigations were able to provide.

The failure to send a shuttle into space and return it safely back to earth was attributed to a single malfunctioning component and the conditions for such component being "allowed" to malfunction were blamed on flawed decision making processes and individual managers making the wrong decisions (Vaughan, 1997). Vaughan contradicts these findings and gives insights into why people have acted in the way they did and what the information available at the time before the launch *meant* to those involved. In this way she provides a much more elaborate analysis of the systemic conditions that enabled the outcome.

In the other example, the failure to provide safe transportation in northern Iraq, the official investigation could not show a single culprit or "*smoking gun*" (Snook, 2002). Snook's account of the events draws on detailed descriptions of the actions in their respective context. He concludes that to make sense of the events a wider view, across organisational boundaries, was required and that any analysis on a single level will miss the mechanism affecting the outcome.

A key lesson that can be learned from these analysis of socio-technical systems is that the way we look at phenomena not only influences, but determines what we are able to see and in the end determines what we are able to find (Dekker, 2006, 2011). This is also known as the "*What-You-Look-For-Is-What-You-Find*" principle (Hollnagel, 2012). Therefore, the model we apply in our view on the relationship between cost and the service system is a determinant for what we are able to find and ultimately do about it.

3 Costing service systems

A firm transforming to a role as service system provider is concerned with the cost of delivering results (Tukker & Tischner, 2006). However, in sectors like defence, the emphasis is placed on quantifying how much has been spent in a certain time-span for the acquisition of capabilities, usually categorised aggregately according to their nature as labour, equipment, materials types etc. (Anagboso & Spence, 2009). By setting the focus of cost analysis on the acquisition of the capabilities acquired (inputs), little or no insight is given at the level of accomplishment (outcomes) pursued as a result of a certain endeavour and its intermediate results (output) (Doost, 1996). A practical example is provided by a recent article on the UK tactical intelligence capabilities namely the Ministry of Defence (MoD)'s Watchkeeper unmanned air system (UAS) programme (Hoyle, 2013). First and foremost, the program is identified in terms of what has been spent on the procurement of a number of aircraft that were not operational. However, as the focus shifts on the target acquisition and reconnaissance services in Afghanistan, it becomes clear that for this to be achieved another UAS had to be leased.

Categorising costs without considering the underlying demand for jobs to be done can be particularly insidious, as Emblemsvåg (2003) points out. This way of categorising provides no indication of whether a reduction of spending in any of these categories erodes the company's future ability to deliver value by meeting customer demand. This, in turn, may trigger more cost cutting – a phenomenon addressed as "*death spiral*" (Chinn (2013) provides an example concerning military-equipment acquisition). In a downturn, companies' intent of cutting costs may inadvertently result in damaging the fabric of their business by cutting "*muscle*" instead of "*fat*" (George, 2010, Coyne, Coyne & Coyne, 2010).

A closer look at the direction taken in academia regarding how to cost services and service systems reveals that the approaches proposed so far lack orientation toward the results that a service system is meant to deliver (Settanni *et al.*, 2011). Often, the cost of a service system is identified with the cost of the in-service phase of a durable product (see for example, Datta & Roy, 2010, Huang, Newnes & Parry, 2012, Jazouli & Sandborn, 2011). Even when a systems approach is explicitly claimed in cost estimation, it is not the case that a representation and modelling of the system structure, elements and purpose explicitly play a role (see for example Hart *et al.*, 2012, Valerdi, 2011).

Approaches like Activity Based Costing have been recommended for the service industry, where the performance and cost of business processes, especially those experienced directly by customer, is crucial for competitive differentiation (Edwards, 1999, Rotch, 1990). The foundation of these approaches is a focus on activities or operations within the enterprise that are structured according to their logical order and dependence, and are aimed to produce a specific result which is of value to internal or external customers (Hansen & Mowen, 2003). To the authors' knowledge, however, only Kimita *et al.* (2009) have proposed a service system costing model based on a representation of a functional service structure, where functions are realized by both human activities and product behaviours that are performed to deliver value with the customer.

The underlying principle is that costs cannot be managed – only activities can (McNair, 1990). Therefore, in this case a cost estimate is an attention focusing device (Cooper, 1990), raising cost consciousness by continuously monitoring the behaviour of the relevant cost over time (Lindholm & Suomala, 2007).

4 What is your cost model?

Cost modelling has been defined as an a priori analysis that maps the characteristic features of a product, the conditions for its manufacture and use into a forecast of monetary expenditures, irrespective from whom (provider, customer, etc.) the monetary resources will be required (Sandborn, 2013). An overview of issues and approaches in cost modelling is outside the scope of this paper and can be found elsewhere (Curran, Raghunathan & Price, 2004). Here, "What is your cost model?" is a re-interpretation of the question "*What is your accident model?*" asked by Dekker (2006) to sensitise for the impact of our preferred view on what we are able to see.

4.1 Cost is an intrinsic property of products

A common view on cost is to assume that cost is a dependent variable that has the propensity to be related statistically to the technical attributes used by the designers to characterise a product or service instance, or other features of a project. This is the view adopted in parametric cost models (see for example, Pugh, Faddy & Curran, 2010). The relationship between cost and these characteristics is typically one of statistical correlation, derived through extensive records of historical data. This model's use is typically focussed on speed of results, and allows changes in product's features through redesign to translate directly and immediately into changes in its unit cost. For example, Valerdi, Merrill & Maloney (2005) adopt this model to calculate the yearly cost of an Unmanned Aerial Vehicle as a function of its payload weight and endurance.

This cost model implicitly reflects an assumption which is commonly made in the literature: a significant portion of a product's cost is locked-in at its design (commonly quoted statistics are typically beyond 80%, see for example Newnes *et al.*, 2008). This assumption suggests, even in the absence of empirical evidence, that focus should be on product development, whilst diverting attention away from actions that can be taken in manufacturing or other downstream activities including use (Cooper & Slagmulder, 2004, Labro, 2006). Placing the responsibility for the costs incurred while the product is deployed exclusively on the designer creates the expectation that cost can be treated as an independent variable, just like any other engineering unit in the design process (see for example, Nicolai & Carichner, 2010).

Being based on a direct relationship between design features and cost (per unit, per year etc.), this cost model also promotes an idealised approach to product design which overlooks the challenge of cost allocation within the existing business environment (Barton, Love & Taylor, 2001). Predefined and known cost figures for the system or component under investigation are expected to be retrieved rather than computed. For example, Romero Rojo *et al.* (2012) propose a model of avionic obsolescence cost for use in service-system contracts in which the base cost of resolving an obsolescence issue must be known.

4.2 Cost is a necessary evil due to cost drivers

Another view on cost rests on an understanding of "cost drivers" as something to drive out and get rid of or minimise. The expression "cost driver" is recurring in both literature and practice, but often misinterpreted. As Stump (1989) points out, cost drivers are often improperly used as synonyms for the cost categories in which costs are classified; the most expensive (high value) item in a product; or the quantifiable product features discussed in the previous section –like weight, etc. – which can be statistically related to the unit cost of a product. For example, Erkoyuncu *et al.* (2011) identify failure rate, turnaround time, repair cost, LRU (Line Replaceable Unit) cost, and labour availability as "…*typical cost drivers that arise at the bidding stage of a contract for availability*".

Underpinning this view on cost is that cost drivers are decision elements that have instantaneous cash flow consequences. These decision elements are usually considered in isolation. Cooper calls these models "*spending models*" (Cooper, 1990). Maintenance, for example, is frequently dismissed as a necessary evil. In such view maintenance efforts are unwelcome activities that drive costs therefore they should be avoided. The positive contribution of maintenance to the final delivery of an outcome, for example sustaining production in a manufacturing plant, is simply neglected (Kelly, 2006, Sherwin, 2000).

For example, Browning & Heath (2009) demonstrate, with a case study of the F-22 production line, that cutting cost can remove the necessary conditions for successful delivery of desired outcome in the absence of an understanding how the system works.

4.3 Cost is an emergent property of a system

Finally, cost can be viewed as determined primarily by the dynamic behaviour of the system delivering products (or services) (Storck, 2010). In this case cost is an "emergent property", and effective cost analysis must rely upon a consistent and transparent representation of the context within which products and services are designed and delivered (Field, Kirchain & Roth, 2007).

Similarly, van der Merwe (2007) highlights that insight is needed into the quantitative flow of goods and services consumed and produced by the enterprise, whereas money is a meta-language providing a corresponding value representation of the quantitative flow.

In this case the knowledge required for the costing operation is more than just data and information (e.g. regarding a product's cost and technical characteristics), rather, focus is on what the information represents, how to handle it and most importantly what action to take (Naylor, Griffiths & Naim, 2001).

Models of virtual cost flows based on means (enabling conditions) and ends (desired outcomes) relationships within a system of interrelated operations have been developed, for example, in the field of material and energy flow costing (Möller, 2010). Another example is the application of Functional Analysis, which bases cost analysis on the functions or services provided through the activities performed within an enterprise and how they are achieved (Yoshikawa, Innes & Mitchell, 1994).

In this view, "cost drivers" are causal events which determine "why" work takes place and how much effort must be expended to carry out the work (Emblemsvåg, 2003). They measure the frequency and intensity of the demands placed on activities performed within an organisation, hence sometimes they express the output of an activity (Raffish & Turney, 1991).

This view of cost drivers allows initiatives for cost reduction to be centred on improved efficiency, which measures the use of resources in activities performed in order to deliver an outcome (Neely, Gregory & Platts, 2005).

4.4 Comparison of perspectives

Table 1 provides a simple example of how the perspective taken towards costing may shape the understanding and action of an organisation, taking the example of the Watchkeeper UAS program. Depending on the perspective of the individual, what is being delivered by the program ranges from a quantity of unmanned aircraft to tactical intelligence. In the latter case the Watchkeeper UAS may only be one option to deliver the outcome. Therefore, the costs incurred would not be attributed to individual assets, but rather to the activities required to deliver intelligence. The achievement of certification, more precisely the time needed to get there, is an example for a program cost driver. Consequently, reducing the time to certification leads to cost reductions.

Table 1 Different views on cost applied to the Watchkeeper (Hoyle, 2013) example.

This example shows that the rationale for making decisions depends on the view we have on a phenomenon. Based on our perspective the meaning something has for us changes and so do our options for taking action.

5 No understanding, no action

One aspect which is rarely highlighted is why a cost estimate is carried out. Table 2 presents some insight derived from selected academic references.

Table 2 Why cost estimation?

Often, the purpose is the generation of a one-time cost estimate independent of specific organisational and industrial settings, sometimes referred to as should-cost estimating (Ellram, 1996). A limitation associated with this purpose is that insight may appear to be less important than "*providing a number"* that will get approval, e.g. for budgeting purposes (Keller, Collopy & Componation, 2014). Underlying a service enterprise, also commonly referred to as Product Service System (PSS), is typically an intent to benefit from long-term strategic alliances, which requires an advanced service provider to understand the whole life cost of a PSS contract (Meier, Roy & Seliger, 2010). The purpose of assessing the cost of an advanced service provided through a PSS should be to provide information to support taking action for continuously meeting contracted levels of performance. This is consistent with the call for a shift of focus on methods of controlling cost, "…*rather than the futile attempt to predict it*" (Keller, Collopy & Componation, 2014). Crucially, information provides insight and understanding only when it is placed in context (Glazer, 1998).

5.1 Understanding directs action to change a situation

Figure 1 illustrates that understanding and actions are intertwined in a continuous process over time. Understanding evolves through continuous updates, taken from available environmental clues about the situation. Understanding is then tested through action in the real world to compare the expected with the actual outcome. Only when an understanding of a situation – including the interactions with the environment – is present can we determine what needs to be known to solve a problem (Ackoff, 1989). How well we understand a phenomenon determines our abilities to anticipate or infer the future behaviour of a system and accordingly whether the actions we undertake can lead to the results we desire. System understanding will only emerge through intellectual effort (Burge, 2010) and costing can only be insightful when it is based on an understanding of the whole delivery system.

Figure 1 Actions are directed by understanding which evolves through update. (Adapted from Dekker, 2006**)**

Attempts to predict properties by reducing the system to characteristics of individual components, or aggregated system characteristics (e.g. Valerdi, 2011), clearly contradict the very foundation of what a system is considered to be. This is namely the inability to derive the system behaviour from its components in isolation, or by neglecting the constituent relationships. Such attempts confirm the observation made by Dekker (2011) that the analysis of systems often remains "*depressingly*" componential.

5.2 Shared understanding through visualisation

It is recognised that in practice it is difficult to give adequate visibility to the processes involved in the delivery of the final outcome of a service system (Batista, Smart & Maull, 2008, Datta & Roy, 2011, Ng & Nudurupati, 2010). They are therefore particularly prone to local adaption and pragmatism by managers tasked to deliver local goals, but whose actions can ultimately lead to the breakdown of the whole. Considering that through the adaption of local habits (Vaughan, 1997, Snook, 2002) informal processes develop that no longer correspond to the –well intended, but static – formulation of official, or formal processes (Christensen & Kaufman, 2009), maintaining a dynamic common understanding of these local behaviours is imperative. The value of information, or in this particular case a cost estimate, is dependent on the meaning it has for the receiver, which is a result of social processes (Jakubik, 2011). However, from a project management perspective consensus about a situation among different stakeholders cannot be imposed; rather, it has to be built (Conklin, 2006). Pictures and diagrams, in short visualisation, are means to facilitate communication (Cooke, 1994) and to achieve a shared understanding among a larger group about the same problem domain (Bell & Badiru, 1993, Snyder *et al.*, 1992). Concept maps are particularly useful to illustrate relationships between elements. They can be more or less formal and may or may not exhibit a hierarchical structure. Interlinks between the elements can be in the form of prepositional phrases, such as 'is a result of', 'leads to', or the like (Davies, 2011).

The Functional Resonance Analysis Method (FRAM) (Hollnagel, 2012) is an approach, to explain outcomes by interactions between system elements. It has been developed for accident investigation and risk analysis. As such it is equipped to deal with socio-technical systems to provide insights into why and how they normally succeed and occasionally fail. One of its foundations is the assumption that success and failure exist for the same reasons. For service provision this viewpoint is highly valuable as the insights provided include the enabling conditions as well as threats for the delivery to be successful. It can capture phenomena across levels, be they individual or organisational. Hence, it is suitable for use in identifying holistic phenomena of socio-technical system (Hollnagel, 2012), such as how the adaption of local practices can lead to global misalignments and ultimately failure (Snook, 2002).

6 "*Houston, we have an epistemological problem!*"

The above discussion has taken us from outcomes delivered by service systems, through the characteristics of systems and the reasons for estimating costs, over possible views on costs to the link between understanding and taking action, which ultimately is the purpose of cost estimation. The creation of understanding is rooted in how we make sense of the world. Perhaps, one of the most effective ways of expressing this is in the words of Dekker:

> *"If the worldview behind these explanations remains invisible to us, [...] we will never be able to discover just how it influences our own rationalities. We will not be able to question it, nor our own assumptions. We might simply assume this is the only way to look at the world. And that is a severe restriction [...].*
>
> *Applying this worldview, after all, leads to particular results [...]. It necessarily excludes other readings and other results. By not considering those (and not even knowing that we can consider those alternatives) we may well short-change ourselves."* (Dekker, 2011)

Ways of "*understanding and explaining how we know what we know*" is the essence of epistemology (Crotty, 1998). Its German translation *Erkenntnistheorie* is, although more explanatory terminology-wise, hampered by the fact that there is no direct translation of the word *Erkenntnis* (Gabriel, 2013). It comprises concepts such as insight, knowledge, understanding and making sense. Therefore, epistemology is what determines how we gain understanding about the world or a situation (as expressed in section 5 "No understanding, no action").

Table 3 shows how our underlying epistemology shapes the way we look at phenomena and may try to tackle them through actions. It is based on two distinct frames of assumptions about the world we live in or the phenomena we want to investigate, dualism versus duality (Schultze & Stabell, 2004). A worldview of dualism or polarities assumes either/or relationships. For example, success and failure are two distinctive and mutually exclusive phenomena and so are service-centric and product-centric worldviews, as well as product cost and service cost estimation techniques (for example Huang, Newnes & Parry, 2012). These categories would be considered as complementing each other in an epistemology based on dualities. With reference to the previous examples, it has been highlighted how failure and success exist for the same reasons (Hollnagel, 2012); also it has been suggested that service system costing should exploit the commonalities between products and service rather than exacerbating their differences (Thenent, Settanni & Newnes, 2012). Park, Geum & Lee (2012) highlight that in the marketing orientated view on PSS products can be separated from services, whilst in engineering-oriented perspective they are organically integrated to provide the outcomes that customers want. Also, the discussion in section 2 "Why service systems have their peculiarities" has shown that service systems exhibit emergent phenomena consistent with a 'both/and' epistemology, such as the inability to gain complete knowledge about them, and success and failure being having the same roots. There is enough evidence in the literature to claim that for service systems approaches that attempt to explain the system behaviour by the characteristics of separated components only provide limited, if any, insight (Wang *et al.*, 2013).

Table 3 Underlying epistemology: dualism versus duality (Adapted from Schultze & Stabell, 2004)

Evidently, the views on cost discussed in section 4 "What is your cost model?" reflect different epistemological standpoints. Understanding cost as an emergent property of a system of interrelated activities (Field, Kirchain & Roth, 2007) undertaken to achieve a purpose suggests costs being rooted in practices, *how* the delivery system works. Conversely, cost being considered as intrinsic property of a product is based on a direct and knowable relation between the product's characteristics, for example through a breakdown structure and its costs (see for example Castagne *et al.*, 2008). Similarly, cost drivers assume a direct causal relationship between specific properties of a delivery system (or product) and costs. These properties can be influenced independently of each other to achieve cost minimisation i.e. eliminate non-value adding costs (see for example Cai *et al.*, 2008). It is the authors' opinion that the literature on costing service-systems endorses an 'either/or' epistemology (contrasting product to service cost estimation techniques) to a 'both/and' situation (a service-system). It does so by focusing on isolated 'pockets of comprehensive knowledge' about the technical system element (the product) of what *should* be considered as a socio technical system.

Such an approach is not without risk. When we take actions based on an understanding derived through an 'either/or' epistemology to a 'both/and' context we cannot expect that the situation changes in the intended way. In fact, we may easily remove the conditions for the system to deliver its function (Browning & Heath, 2009). Therefore, before a tool for decision support is employed one should ask whether the assumptions underlying such tool are indeed appropriate for the situation at hand.

When defining the boundaries of the system of interest, a sharp distinction between complete knowledge within the boundaries, and the absence of any knowledge outside of the boundaries should not be expected. Rather, varying degrees of incomplete knowledge will shape *blurred boundaries* around the system under investigation. The boundaries, as stated in section 2.2 "Service systems are socio-technical systems" are reasonably defined according to the purpose of the system investigation which also drives the required knowledge within these boundaries. "Opaqueness" is the term used by George (2010) to describe the differing insights different stakeholders have about the same phenomenon, in his example business processes. Depending on the knowledge required appropriate methods need to be employed. A database rich of product data may not provide the desired insight into labour-intensive business processes that are shared with the customer, such as typical for service systems (Ng *et al.*, 2011). Interviews by contrast are well suited to unveil not only what is happening, but also *why* and *how* things are done (Naylor, Griffiths & Naim, 2001).

It is shown by George (2010) that high performing companies approach cost reduction opportunities based on diagnostics and understanding, whereas average performers arbitrarily. We should therefore critically question what is known about cost and how it is known. In the absence of an agreed framework that reflects the epistemological needs of cost estimation for service systems practical advice can only be focused on how to approach a situation. Table 4 summarises the aspects discussed above to provide guidance for what needs to be known and how it can be known. To avoid applying unsuitable methods careful consideration should always be paid to the underlying assumptions about the situation at hand, as shown in Table 3.

Table 4 What needs to be known to estimate the cost of a service system?

7 Conclusion and future work

Management decisions are frequently based upon distinct worldviews on costs that are reinforced by experts, but insightful costing remains a challenge. As systems rather than products are procured some of the weaknesses of the standard approaches to cost modelling deserve more attention. The way a cost is to be used has an impact upon the way it might be calculated. Further, the perceptions of different managers will influence how costs are built up within a cost model and there are no guarantees that the different elements of the cost models are all built upon a shared set of common assumptions. A greater understanding of what we know and how we know it, the epistemology, is required. The relationship between underlying epistemology and cost modelling approaches shows that philosophical grounding is not just something for those in the ivory towers of academia. Instead, it has important practical relevance for managers as epistemology determines the chosen view on the world and accordingly influences what managers are able to do and what they may try and change. This is in line with previous findings in the field of engineering and service science (Batista, Smart & Maull, 2008, Emblemsvåg & Bras, 2000).

Methods to deal with these challenges are available, such as FRAM, although not in the field of cost estimation. Therefore further work is required to adapt these methods to the needs of cost estimation while retaining philosophical consistency. A case study is currently underway that aims to deliver a practical approach including a proof-of-concept of a computational structure which is based on a qualitative representation of the service system.

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Cutting cost in service systems: Are you running with scissors?

Table 5 Different views on cost applied to the Watchkeeper (Hoyle, 2013) example.

	Cost is an intrinsic product property	Cost results from cost drivers	Cost is an emergent property
Delivery	A number of UASs.	A certified UAS.	Tactical intelligence.
Origin of costs	Wing span or weight of the individual UAS.	Extended time for certification.	Activities necessary before, during and after deployment.
Possible means for reduction	Reduce UAS size.	Expedite certification.	Manage activities.

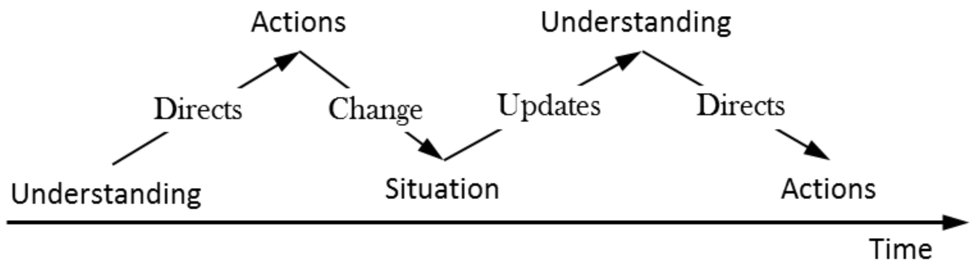

Figure 2 Actions are directed by understanding which evolves through update. (Adapted from Dekker, 2006, p. 136)

Table 6 Why cost estimation?

Reference	Statement of purpose
(Stewart, 1982)	"To assure maximum productivity, it is necessary to have an accurate estimate of the costs required to accomplish a job before it started and to efficiently and effectively manage the job within the cost constraint established".
(Korpi & Ala-Risku, 2008)	To support: affordability studies; source selection studies; design trade-offs; repair level analysis; warranty and repair costs; sales strategies.
(Newnes et al., 2008)	To help designers to modify a design in order to achieve both proper performance and cost.
(Roy, 2003)	To influence the go or no-go decision concerning a new development.
(Xu et al., 2012)	"In Cost Engineering, normally knowing cost is not the final aim. More often, it is desired to know where to reduce cost and if customers can afford the product/project cost."
(Ellram, 1996)	Understand the true cost of buying a particular good or service from a particular supplier.
(Asiedu & Gu, 1998)	(1) Alternative system/product operational utilization and environmental profiles (i.e. consumer user plans); (2) Alternative system maintenance concepts and logistics support policies; (3) Alternative equipment design configurations (4) Alternative production approaches (5) Alternative procurement sources and the selection of a supplier for a given item; (6) Alternative product distribution channels (7) Alternative maintenance plans (8) Alternative product disposal and recycling methods; (9) Alternative management policies and their impact on the system.

Table 7 Underlying epistemology: dualism versus duality (Adapted from Schultze & Stabell, 2004, p. 554)

	Either/or (Dualism, polarity)	**Both/and (Duality, complement)**
Theoretical frame	Categories (e.g. breakdown structure).	Practices, pragmatism.
Characteristics of investigated phenomenon	Object is frozen in time; phenomena have a separate identity.	Object is continuously shaping and being shaped by situated practice; phenomena are mutually constitutive.
Causality	Uni-directional; deterministic.	Cyclical, circulating, emergent.
World	Finite; completely knowable.	Infinite within parameters (i.e. constantly changing yet staying the same); not completely knowable.
Place for paradox / contradictions	Contradictions do not exist; they are a sign that categories and models are not sufficiently granular.	Embraces contradiction and paradox; considers opposing forces operating simultaneously.
Success / failure	Can be distinguished and failure can be eliminated.	Both have the same origins.

Table 8 What needs to be known to estimate the cost of a service system

Question to ask	Consequence
What do we want to do?	Herewith we define what is inside and outside the boundaries of the investigation or model.
What do we need to know about?	Deliberate actions can only be taken on known elements and relationships inside the boundaries.
What can we know?	Depending on the methods employed different insights can be gained. It is important to understand that a service system is nothing that can be readily observed; rather it needs to be constructed.
What do we know about costs?	Herewith the current practices of computing costs, or adding up invoices is questioned. It provides insight whether these are fit for the intended action to be taken.