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Complex Engineering Service Systems

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Because things are the way they are, things will not stay the way they are

Bertolt Brecht

Foreword

Creating value in any service market depends on many key factors. These include the ability to work closely with customers, partners and suppliers; the ability to anticipate customers' future requirements; and the ability to integrate and optimise business processes, people, tools and information to create value-added service systems and solutions.

In today's business environment, increased pressure on budgets means that customers are increasingly looking for greater value for money, and long-term service contracts to support complex engineering products are becoming the norm. Customers for complex engineering products are not passive recipients of goods; they recognise the need for close integration of service systems with their own business systems and are taking an active role in working with their suppliers to ensure those services deliver the outputs they need in an affordable way.

BAE Systems is not only one of the world's largest manufacturers in the defence, security and aerospace sectors; it is also one of the largest service providers in this industry. We have some of the best engineers in the world, creating highly complex engineering solutions for our customers, and providing support and services for these products requires complex engineering service systems. As well as integrating industrial capabilities, complex service systems are often embedded within a customer's organisation, with multiple supply chains and an extensive network of subordinate service providers.

The field of complex engineering service systems is a developing area of interest for both ourselves, as industrial practitioners, and the academic researchers with whom we collaborated in the areas described in this book. As an organisation we have had the privilege, along with the UK Engineering and Physical Sciences Research Council, of supporting the research undertaken by the Support Service Solutions: Strategy and Transformation Project (S4T), upon which this book is based.

The research carried out in this field has helped us to explore and address the complexity of the challenging new environment in which our business operates to support our customers better. Working with the S4T researchers and academics has given us insights and different perspectives into what underpins value-added service offerings.

Complex engineering service systems do require new ways of thinking; changes in mindset and an evolution in business models, processes, organisation, tools and information management, to deliver continually improving performance over product lifecycles that span decades. Our commitment to research in this field is about investment in our future, to maximise our potential and to provide the highest levels of service and best value for money for our customers.

I am proud that BAE Systems has supported the work described in this book. It follows many years of association between people in the company and the University of Cambridge and its Institute for Manufacturing, and other institutions. The result is a very powerful mix of academic research, innovation, rigour and above all systems thinking, all being driven by clear business requirements as we break new ground in this field. I am delighted to see the results of these collaborations being published.

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Finally, all the editors and the authors would like to thank our families. Organising, directing and researching for the S4T programme as well as putting a book together is unavoidably intrusive on family life. Producing a book with so many contributors is always a challenging experience and this would have not been possible without our families' ongoing support and understanding.

Contents

Chapter 1
Towards a Core Integrative Framework for Complex Engineering Service Systems

Irene Ng, Glenn Parry, Duncan McFarlane and Paul Tasker

Abstract Complex Engineering Service provision is a developing area for both practitioners and academics. Delivery requires an integrated offering, drawing upon company, customer and supplier resources to deliver value that is an integration of complex engineered assets, people and technology. For a business to present a sustainable value proposition, managers are required to develop a diverse skill set, working dynamically across previously separated business areas with established company boundaries. In this chapter we will present a framework for complex engineering service system that is value-centric and that conceptually integrates the chapters of this book. The framework proposes that the provision of service requires companies to be capable of working together with their clients to create value through three integrated transformations: people, information and materials & equipment. Successful provision of complex engineering service solutions therefore requires the integration and mastery of many different disciplines that bring about these transformations as well as understanding the

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interactions and links between both the transformations and the disciplines. The challenge laid out in this chapter and developed throughout this book explores this new environment, providing guidance and identifying areas requiring future work.

1.1 Introduction

Provision of goods has been a hallmark of manufacturing since the start of the industrial era. Indeed, as early as 1776, Adam Smith proposed that the wealth of nations was built upon a country's ability to produce an excess quantity of goods and then export this excess to generate wealth. This provided the foundation for the dominant view of goods as the staple for value creation.

The key category of manufactured goods is 'equipment': systems generated to provide a transforming function of their own. As equipment provision has become more complex and as competition heightened, firms have felt the pressure to add value, predominantly through the provision of services. Research has shown that manufacturers provide services in the form of training, integration with clients' capabilities, consultancy and other services related to the provision of equipment (Ren 2009). Indeed, for many manufacturers to remain viable, research has shown that they may need to diversify into the provision of services (Neely 2008). This provision has been commonly referred to as the servitization of manufacturing.

Servitization has been discussed widely, frequently through an examination of the move by manufacturers to generate greater returns by providing through-life support for their products (Vandermerwe and Rada 1988; Matthyssens and Vandembempt 1988; Anderson and Narus 1995). The hazards and enablers to the process of servitization have also been studied (Oliva and Kallenborg 2003; Mills et al. 2008). However, due to the established paradigm that production of goods is the basis of wealth creation, much of the discussion and analysis of engineering service has been through the lens of goods-based thinking:

> because manufacturing has been the dominant economic force of the last century, most managers have been educated through experience and/or formal education to think about strategic management in product-oriented terms. Unfortunately, a large part of this experience is irrelevant to the management of many service businesses (Thomas 1978)

This raises the challenge for academics to question the assumptions upon which conclusions are being drawn.

1.2 Theoretical Foundations

Servitization has resulted in combinations of offerings to generate value from both products and services in bundled packages. These combinations of products and services have been called Product Service Systems (PSS). Baines et al. (2007)

defines PSS such that they embody "*an integrated product and service offering that delivers value in use*", highlighting the importance of value. This introductory chapter provides a value-centric integrated framework for Complex Engineering Service (CES) systems which aims to deliver value to the customer through a system of people, processes, assets and technology and the interactions between them rather than the function of the individual components themselves. Such a value is emergent from the CES system and not from a linear chain of operations optimised individually. The understanding of CES systems requires individuals within organisations to develop new skill sets as traditional boundaries are challenged and this presents further challenges as the current component, business unit or functional operation of firms creates power bases that may provide resistance to change. The trans-disciplinary challenge is also true for academics wishing to understand and capture the nature of this new CES system as here too, reductionism is the dominant logic, with teaching split into subject disciplines without focus on the interaction between them.

The move from design and manufacture of equipment and its corresponding capabilities to a combination of activities and assets to achieve consistent and high value outcomes is crucial to a world of depleting resources and to the global sustainability movement.

The concept of value has long been discussed in academic literature. Organisations have been called upon to deliver superior customer value as a major source of competitive advantage (Payne and Holt 2001; Eggert et al. 2006; Liu et al. 2005; Ulaga and Eggert 2006). Similarly, value and customer orientation is echoed amongst academics in different fields (Cannon and Homburg 2001; Chase 1978; Amit and Zott 2001; Ramirez 1999; Kim and Mauborgne 1999). Indeed, Ravald and Gronroos (1996) claimed that a firm's ability to provide superior value is regarded as one of the most successful competitive strategies in the nineties. Within business-to-business (B2B) literature, delivering superior customer value assists firms in developing and maintaining strategic buyer–seller relationships (Liu et al. 2005), resulting in loyalty (Bolton and Drew 1991) and the potential to grow margins and profits (Butz and Goodstein 1996). From the practitioner's domain, Drucker (1993) proposed that what value means to the customer is one of the most important questions a business should ask. Thus, practitioners and academics alike have stressed the importance of delivering customer value as the key to success.

The traditional notion of value is that of exchange value which underpins the traditional customer–producer relationships, where each party exchanges one kind of value for another (Bagozzi 1975), with something in exchange for something else. However, contemporary literature has moved the discussion of value away from this understanding to the concept of value-in-use (see Vargo and Lusch 2004, 2008; Schneider and Bowen 1995), which is evaluated by the customer rather than the currency for the transfer of ownership of a particular "good". Value-in-use, described by Marx, is "value only in use, and is realised only in the process of consumption" [Marx 1867 (2001), p. 88]. In this regard, value and quality are therefore significantly harder to conceptualise due to the requirement for the customer to contribute to the service creation (Parasuraman et al. 1985), the notion of *value co-creation*, as we will see from the book's chapters. Thus, as proposed by Ballantyne and Varey (2006), the exchange value implicitly includes an estimate of the value-in-use of any "good" and activity that has been contractually exchanged or promised for consumption. Sellers of services must focus upon use through a relationship, ensuring the clients remain satisfied after the point of exchange through constructive engagement, resolving their complaints and meeting their future needs. Consequently, whether benefits to customers are attained through tangible goods or through the activities of firms, a customer-focused orientation would focus on value-in-use, delivered by the outcomes rendered by a combination of equipment and activities. Where activities are often tacit and heuristically driven and the equipment is highly complex in engineering terms, the capability to design and deliver value becomes a challenge. This is thus the book's foundational premise.

A goods-centric legacy from the industrial era has embedded processes, systems and knowledge for the production of tangible products, which has been effective in delivering high quality equipment, to the level of 'six-sigma' and the like (Nonthaleerak and Henry 2008). As manufacturers add 'service' to the body of goods-centric knowledge, the tendency is to treat services as an extension of that body of knowledge. This is theoretically problematic for three reasons.

First, value in use for service activities would immediately imply an inseparability of production and consumption (de Brentani 1991; Ng 2009). By its logical extension, the delivery of value-in-use in service could happen at any and all encounters with the customer, as the customer 'uses' the service. A goods-centric legacy of linear production processes towards some tangible end may not hold for value that is amorphously delivered through a multitude of touchpoints with the customer.

Second, the *use* of tangible goods to achieve benefits is often conducted by the customer away from the firm that manufactured it. Thus, for the manufacturing of goods the responsibility of the firm ends at production or when the ownership of the product has been transferred. In the delivery of service activities, however, the firm's responsibilities often *include* the customer where the customer's capability to use the service becomes the firm's responsibility as well, so that beneficial outcomes could be attained. A goods-centric mindset with boundaries of where 'production' ends may imply that the firm is only responsible for the delivery of 'service activities' which they undertake when faced with their customer. Such a mindset results in a lack of motivation to truly understand how customers co-create value with the firm, resulting in poor service outcomes.

Third, achievement of excellent service outcomes, as opposed to excellent product outcomes, is through the contribution of resources by both the firm and the customer. Traditional manufacturing systems, processes and knowledge frequently exclude the customer resources in delivering a manufactured good. It may even be proposed as a necessity to achieve consistent, high quality tangible goods. This approach may need to be changed and the access to and integration with a customer's systems, processes and knowledge are proposed as a necessity for the delivery of high quality service.

To achieve a better understanding of this approach to service without the baggage of goods-logic, some academic researchers have turned to service management research. Service management research, like research into production, has a long history (Huang et al. 2009). Early work focussed upon goods as tangible objects and services as intangible and a form of 'performance' (Say 1803; Senior 1863) and the concept that production and consumption are separate for goods, but may be instantaneous for service (Hicks 1942). The intangibility and interaction between producer and consumer formed two of the key building blocks for the IHIP service definition [intangible, heterogeneous, inseparable and perishable] which has been a touchstone for many service researchers (Kotler 2003). However, much of this research is focused on service contexts that are inherently more intangible in nature, such as hospitality, tourism, banking or telecommunication. Even where tangible goods are involved, the goods are a component of the service. In the way manufacturing researchers treat activities (services) as an extension of manufactured goods, service management researchers often treat tangible goods as merely a part of service activities, indicating that a service provision would range from greater tangibility e.g., cosmetics, to highly intangible e.g., teaching and education, on a spectrum (Shostack 1977). Such a point of view is also theoretically problematic.

While it is always possible to strategically distinguish between equipment and people-based service offerings (Thomas 1978), it may not be meaningful. This is because the operation of equipment may require different levels of skills. Thus, equipment design and manufacture has to consider what is appropriate for the market need and the cost of provision, whilst at the same time considering the skills of the customer. For example most vending machines or carwashes are fully automated and require very little skill to operate; dry cleaning equipment and the projector in a cinema require relatively unskilled operators; civil aircraft require highly skilled operators. The point is that from a value perspective, equipment within a service environment is not unchangeable, particularly for engineering. They are designed for ease of use and appropriate operability. Thus when customers use equipment or goods that include service activity provision it is essential that the combined offering delivered is integrated effectively to best serve the customer's requirement as well as being efficiently constructed for the firm. This means that the equipment could be engineered and designed to facilitate service activities provision just as processes and activities executed by service personnel could be redesigned for better outcomes. For example, designing vehicles for ease of service and repair became part of the focus of the thinking of German Porsche automobile company, reducing the cost of service and maintenance at a later time (Womack and Jones 1996, pp. 194). Particularly where service activities are tied to equipment provision such as in the case of complex engineering equipment in healthcare (MRI) or defence (fastjets), the understanding of use and outcomes required by the customer over time could allow the organisation to change business models, charging for use or outcomes (e.g., power by the hour® by Rolls Royce) instead of equipment ownership. By not separating equipment from activities and instead, focusing on benefits and the value offering in totality, firms could also innovate for better outcomes and achieve efficiency gains from redesigned and re-engineered equipment that enable better service activities. There is still great scope in both manufacturing and service fronts for exploring interactions between equipment and services in creating service as an experience (Pine and Gilmore 1998). More advanced knowledge on how equipment and service activities integrate and interact to deliver the outcomes is required.

Much of the research behind services and systems integration resides within the information, communications and technology (ICT) literature where systems integration has traditionally been about linking together different computing systems and software applications physically or functionally. Service related research in the field of ICT has been growing significantly in recent years. Zhao et al. (2007b) has provided comprehensive definitions on service computing, which refers to an emerging area of computer sciences and engineering that includes a collection of techniques, such as web services, service-oriented architectures, and the associated computational techniques. Various other similar terms have been used, such as services computing, service engineering, software as a service (SaaS), service-oriented computing and service-centric computing (Zhao et al. 2007a). Moreover, the issue of service-oriented technologies such as web services (Curbera et al. 2003, Brown et al. 2006; Demirkan and Goul 2006) and service-oriented architectures (Spohrer et al. 2007) has also been the attention of many information systems (IS) researchers who have endeavoured to design an integrated service offering.

There are two theoretical criticisms of ICT research, both of which have come from within the ICT domain. First is its focus on modularity and mechanistic designs. ICT research often endeavours to modularise the service offering, where modules are designed such that component interfaces are standardised, and interdependencies amongst components are decoupled (e.g., Ulrich 1995; Sanchez and Mahoney 1996) so as to enable the outsourcing of design and production of components and subsystems, within a predefined system architecture. Thus, ICT research has often taken on the mechanistic, modular approach towards technology, processes or people into some sort of component-based architecture, so that the mixing and matching of modules could provide a best-of-breed system (Lyons 2008). In a complex system offering of goods, people, activities and technology, research has shown that components do not normally ‘click and play’. Indeed, a full specification of an entire system often does not plan for interactions that could result in unpredictable emergent properties (Prencipe et al. 2003; Ng et al. 2009).

Second, ICT research often over-emphasises the importance of technology in value offering. To achieve value-in-use, the integrated offering of goods, activities, people and technologies need to be effective in an *integrated* fashion, grounded on how the customer could *best engage* with the service to achieve benefits, *as well as* what is easiest or efficient for the firm where, in certain cases, less technology could result in better outcomes.

In summary, the idea of ‘adding services’ to manufactured goods is based on a flawed assumption that service activities are mere extensions of knowledge acquired in manufacturing goods. Similarly, service provision should not look upon equipment manufacture as exogenous to the offering, even if it is less flexible to redesign. A firm may have bundled resources that may be catalogued, but the services those resources deliver are only realised during activity. Finally, technology may play a key role, but only as a way to enable value co-creation. From all these perspectives, the need for a revolutionary rather than an evolutionary approach is necessary.

1.3 Complex Engineering Service Systems: Core Transformations

This book aims to reconcile the various streams of research through a value-centric approach. Woodruff (1997) presented the following definition of customer value:

> Customer value is a customer's perceived preference for and evaluation of those product attributes, attribute performances, and consequences arising from use that facilitate (or block) achieving the customer's goals and purposes in use situations.

Taking this value-centric approach, what operations need to be undertaken to deliver value? A value-centric approach must therefore put value-in-use at the centre of what the firm needs to deliver, in partnership with the customer. Consequently, to achieve value in use, the firm has to ask how value is created and understand the role of the customer within that space (Lengnick-Hall 1996). Operations Management literature has proposed that firms deliver three generic transformations. These three generic types of operations are often used to distinguish between organisation types. They are categorised on the basis of their transformation process such as 'material-processing operations', 'information processing operations', and 'people-processing operations'—and academics have discussed the various managerial challenges which differ across the three archetypes (Morris and Johnston 1987; Ponsignon et al. 2007).

The three transformations are explained below:

- Transform materials and equipment (i.e., manufacturing and production, store, move, repair, install, discard materials and equipment through supply chain, repairs, obsolescence management, predictive maintenance)
- Transform information (i.e., design, store, move, analyse, change information through knowledge management, information, communication and technological strategies, data strategies in equipment management)
- Transform people (i.e., train use, change use, build trust through education, influence, build relationships, change mindsets)

Operations literature has usually considered one type of transformation to be dominant (e.g., Slack et al. 2004). Hence, hotels, schools and hospitals are about transforming people, manufacturing and production are about transforming

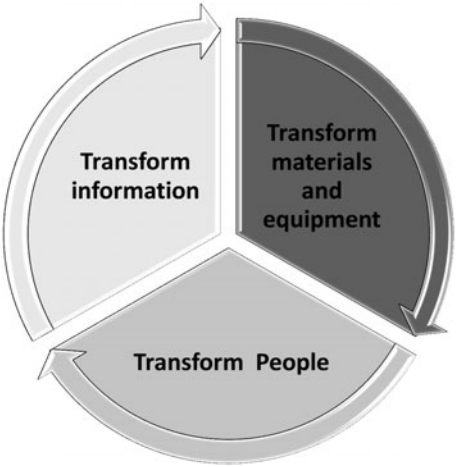

Fig. 1.1 Simple core integrative framework (CIF-lite) for complex engineering service systems

materials and equipment and media and information services such as Reuters and CNN are about transforming information.

While the three transformations are useful to depict a particular industry or sector, this model has an extended applicability to engineering services. In the service and support of complex engineering equipment or systems, such as airports or city transportation, what the customer considers as value, or experiences as value in use, may no longer be delivered through only one form of transformation but *simultaneously through all three*, particularly if the contracts are outcome based (Ng et al. 2009). For example, consider the maintenance repair and overhaul service of complex equipment such as ships, fastjets, submarines or tanks. Materials and equipment transformation would be concerned with repair, maintenance, supply chain and logistics, information transformation would be concerned with technology, information systems and communication with the customer, and people transformation would be concerned with how customer and the firm employees learn, react, use the equipment and interact with one another. Even in early research (e.g., Lengnick-Hall 1996; McDaniel and Morris 1978), customers have been proposed as a key outcome of transformation activities. To meet the full value in use of the firm's offering three integrated simultaneous transformations are required. This provides us with a Core Integrative Framework (CIF) and is shown in Fig. 1.1. The nomenclature reflects the development of a more detailed CIF, bringing in key learning from the chapters, which is presented at the end of the book.

When tasked to deliver the three transformations as the firm's value proposition to the customer, its respective delivery processes now interact with one another and there is no guarantee that the processes and knowledge for each transformation will complement each other if the delivery of all three was not designed into the system. In a CES system the three core transformations form part of the integrated value proposition, delivered through a value constellation (Normann and Ramirez 1993) and co-created with the customer.

The knowledge required to understand the various issues in complex engineering service systems is, therefore, twofold: first, component knowledge of each type of transformation; second, architectural or system knowledge which provides understanding of integration and how the value proposition will enable value co-creation with the customer. Both types of knowledge are essential to inform research into complex engineering service systems. However, research into component knowledge needs to be mindful of the whole, whilst research into system knowledge has to understand that the reduction of the system does not mean reduction of the system into components. Yet, there is a temptation to reduce the CES system into its components for ease of analysis and understanding. Indeed the standard scientific approach surrounds the 3R's of reduction, repeatability and refutation (Popper 1972). This has arisen essentially because many problems are complex and it becomes much easier for scientists to select some aspects of a problem for further detailed investigation. Science follows Descartes' advice to analyse problems piecemeal, that is, breaking down a phenomenon into its elemental parts. Accordingly, scientific thinking is very closely associated with analytical (divided into its constituent elements) thinking.

However, the reductionist approach is based on a number of assumptions that we should consider before applying it to the problems of engineering solutions that include equipment, human and technology interactions. The first and most crucial assumption is that when dividing the complex problem into separate parts, we assume that the elements of the whole are the same when examined independently as when they are examined as a whole. This needs careful consideration. If the elements are loosely connected then we can take them apart, analyse them, improve or change them and then put them back together and the whole will be improved. Whilst this may be true for the problems of simple mechanical systems, does this assumption hold for complex wholes? For example can we take out a part of the body e.g., the heart, modify it replace it back within the body and not expect effects elsewhere?

Lipsey and Lancaster (1956) and Goldratt (1994) have identified implications for the performance of parts where there is a close relationship. Goldratt pointed out the implications of optimising one part of a whole process that was not the limiting step. In his theory of constraints he points out that optimising the performance of a process step upstream of the bottleneck will only increase work in progress and working harder downstream is limited by the output of the bottleneck (Goldratt 1994). Sprague (2007) sums this up neatly proposing that "Optimizing the supply chain means convincing elements within that system to accept local sub optimums for the good of the whole" (Sprague 2007). We argue that this holds for any system rather than just supply chains. Thus, if we want to understand the performance of the whole service system and if we have begun the understanding by reducing to components, we would in essence be making three highly questionable assumptions; first, the connections between the parts must be very weak; second, the relationship between the parts must be linear so that the parts can be summed together to make the whole; and third, optimising each part will optimise the whole. Our understanding of the three concurrent transformations would reject these assumptions as, with value co-creation and customer variability as core factors, complexity becomes an inherent attribute of a through-life engineering service system.

Complex systems may be characterised by the interdependence that exists between the parts which make up a whole (Anderson 1999). Managers may create the value proposition but must remain flexible and adapt to embrace change as outcomes are emergent (Kao 1997; Snowden and Boone 2007; Santos 1998). Organisational effectiveness is increased by 'fit' between structures and organising mechanisms and the context in which they operate (Drago 1998; Brodbeck 2002). But single organisations rarely own or control all the capabilities necessary to deliver complex product systems. Bundling service in the business model increases the complexity, which can be compounded through social and political complexity between internal and external parties (Gann and Salter 2000). Gatekeepers stand at an organisation's boundaries and translate information between the internal and external world of the enterprise (Lissack 1997). Standard processes of interaction would provide greater clarity of communication, but the application of rigid procedures would destroy the adaptable nature of the system. The gate keepers' interaction with other business units, suppliers and customers requires greater understanding and study.

Competitive advantage may be gained through creating the capability to continuously adapt and co-evolve within the complex environments created, embedding a system capable of undergoing continuous metamorphosis in order to respond to a dynamic business landscape (Brodbeck 2002; Lewin et al. 1999). However, the rewards for the suppliers may not correlate with their capability as it is suggested that it is the customer's perception of complexity, not that of the supplier which determines its contractual behaviour (Wikström et al. 2009). The dynamics and complexity of the system are further influenced by two key variables, both driven by value co-creation with the customer. First, contracts delivering service and support of equipment and people may range from merely supplying parts to delivering the availability of the equipment or to delivering the full capability of the customer. Thus, the degree of value co-creation could be contractually bound. Complexity arises when the firm shares resources across multiple contracts with different degrees of partnerships with the customer.

Second, Woodruff (1997) and Ng (2007, 2008) observed that customer value concepts differ because of time and context. For example, the firm and the customer could be engaged in set tasks and activities together and yet the benefits are different because of the context. This is the case for customers that face high environmental variability such as in defence where the support of equipment and people has to be designed to cater for delivery in a diverse set of environment, from Afghanistan to training around the barracks. Thus, customer variability in realising value needs to be factored into the design of the service system.

These system dynamics need to be recognised and organisational competency developed to meet the evolving customer need through transformation. Transformation is an active process, implying a change of state from a current to a future condition. The notion of service transformation, taken from a manufacturing

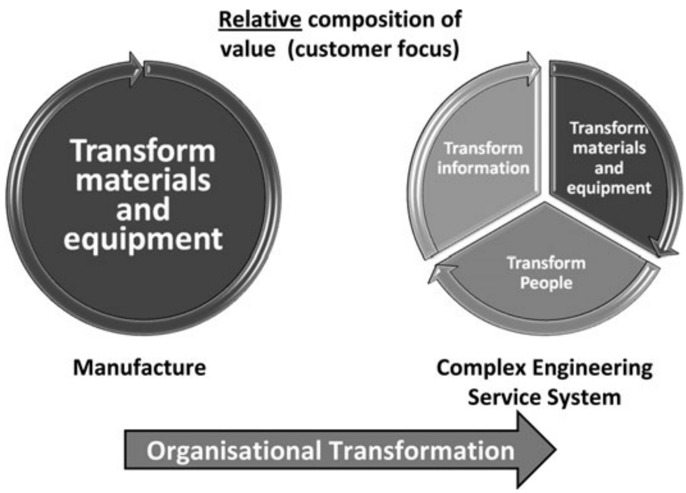

Fig. 1.2 Transformation challenge from manufacturer to partner in integrative service delivery enterprise

perspective, is embodied in Fig. 1.2, where the manufacturing organisation is engaged in a transformation from that which primarily delivers the value of equipment manufacturing (i.e., the transformation of materials and equipment set within the context of value in exchange) as the main value to the customer, to that which delivers the value of transforming materials/equipment, information *and* people (i.e., all three concurrently constituting value, working *with* the provider understanding value in use), and *in partnership with the customer,* through the realisation of value co-creation.

Thus, we define *CES Competency* as the ability of the firm to design, deliver and manage the entire CES system that is able to carry out the three core transformations above in a consistent, stable and profitable manner, co-creating value in partnership with the customer. The development of CES competency is core to companies engaged in the provision of complex engineering service. The competence to work in this dynamic environment will be highly valued by customers who realise greater value when working through partnerships.

1.4 Practice Implications

This book arose out of a research project entitled Service Support Solutions: Strategy and Transition (S4T), a £2m project co-funded by the UK Engineering and Physical Sciences Research Council and BAE Systems. Yet, the research on which this book is based draws on a wide base of academic experience and is directly applicable to other sectors struggling to contain and reduce the cost of those services which are dependent on the sustainment of complex, long life engineering assets.

In the case of defence, government and taxpayer interest is in the ability to deploy a defence service, essentially to provide the warfighter with the ability to have the required military effect in accordance with sovereign political will. This necessarily involves the cooperative working of a range of "customer" and other public sector agents with a wide range of industrial agents working at a national, if not a global scale. Each actor in the network is providing services to others all focused on the overall objective of providing military capability with a central theme of sustaining complex engineering assets, infrastructure and logistics from which the value in use is as dependent on the customer and on the training of operators, as it is on industrial efficiency. Operational and usage information is required to effectively configure service delivery. The driving question is: how is the overall service network best configured, how are its capabilities best integrated and how are the underpinning assets best sustained to assure availability of the desired overall service (military capability) at minimum cost?

It is suggested that there is little difference in principle between the defence perspective on CES systems and that of other industries where a user service is dependent on a complex and integrated delivery network reliant on complex, long-life engineering systems. Obvious examples are: utilities—electricity, water and gas—all of which have a complexity of service and/or "commodity" providers and distributors largely sharing a complex and ageing infrastructure; mass transportation—particularly rail with a similarly complex range of service providers with separate but common infrastructure provision; or medical services—particularly at regional and national level with many users, service agents and a wide range of assets and infrastructure.

Although the primary research base for this book has been defence, it is argued that the resulting insights will have a broad applicability. However, the book is developed from action-based research such that the underpinning case studies are mostly (but not invariably) based on defence and BAE Systems' programmes in particular. Much use is made of the Tornado ATTAC programme (Availability Transformation: Tornado Aircraft Contract) for case study material: this was initially a specific response by BAE Systems and the Ministry of Defence to the escalating cost of supporting the UK fleet of fast jets with early success recognised by the National Audit Office (NAO 2007). Whilst the ATTAC approach is becoming the norm for the provision of "sustainment services" in the defence air sector, it is arguably helping to point the way towards the development of more integrated defence services which will be a better value for the UK taxpayer and is identifying the issues associated with the co-creation of value between user, customer/owner and service providers which need to be addressed in such complex service systems. Clearly much more that can be done and the principle aim of this book is to identify potential further steps for both practitioners and researchers interested in developing the industry's capability to deliver increasingly effective CES systems.

The work reported in the book does draw on other case studies: all are introduced within the chapters which draw on particular insights or data so that the individual chapters are able to stand alone. Defence air is perhaps disproportionately represented because it is acknowledged, in many respects, to be leading the practice in the field. Other studies covered in defence are naval, land and missile systems, in the civil sector, developing experience in commercial air and some "business to consumer" services reliant on logistics and technology such as breakdown recovery. Tentative conclusions are drawn on a case-by-case basis. Whilst the integrating framework provides an overall architecture within which the chapter subjects, case studies and the resulting insights may fit, it is too early to draw any overall conclusions.

One thing is clear: there is a developing imperative for users, owners and operators of complex infrastructure and other engineering assets to improve "value in use", and this is dependent on the development of service delivery networks that are highly integrated, both behaviourally and organisationally, towards the co-creation of value and which have efficient (or lean) engineering management of the assets on which the service depends at their centre.

We consider the key dimensions of CES systems as: service performance and operational management, the service supply network configuration and capability and the engineering associated with efficiently sustaining the assets in service over very long lifetimes. Service performance and operational management is about ensuring that the customer and stakeholder needs are met and that users experience a value in use to at least match their expectations. These services are invariably provided as a result of integrating capabilities and individual outcomes across an extensive network of agents—within a complex customer organisation, with multiple supply channels and with a multitude of subordinate service providers. And the engineering is truly challenging—these systems are being asked to operate at the extremes of their performance availability over lifetimes spanning decades. Frequent updates are needed to sustain or improve performance, operating safety or environmental impact whilst increasingly efficient means need to be found to deliver system maintenance which usually represents a significant proportion of the overall service cost.

Although the case studies on which the research reported in this book is based cover only aspects of this overall picture, it is suggested the complexity of defence systems provides a good start towards understanding the imperatives in what is essentially a new field of study and practice. In describing the case studies in each chapter, authors have tried to reduce the "defence jargon" as much as possible in order to help understanding of potential broader application. Where insights and tentative conclusions are drawn these have, wherever possible, been expressed in generic language.

1.5 Three Core Transformations as a Structure

The Core Integrative Framework (CIF) is foundational to research into the provision of CES systems, providing a basis for communication, understanding and integration. It was with reference to the framework and transformations that this

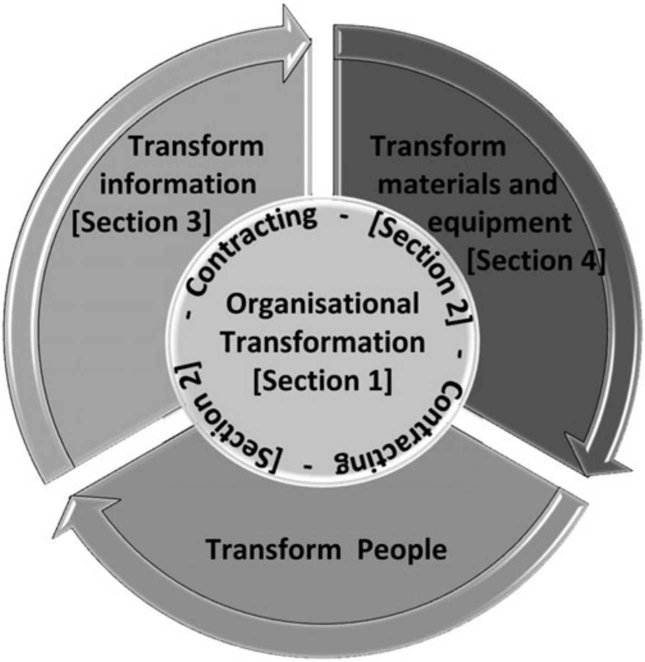

Fig. 1.3 Transformation challenge from manufacturer to partner in integrative complex engineering service system

book and the contributions from authors were shaped. The outline of the book is mapped onto the CIF in Fig. 1.3.

Part I of the book will address Organisational Transformation. The work explores the meaning of Service Enterprise and how transformation may take place. The challenges involved when transforming a complex multi-organisational service enterprise are examined. The section further presents developmental tools for enterprise transformation. 'Enterprise Imaging' describes a methodology used to visualise multi-organisational entities that co-create value. The output of the tool is an image of the organisation that is to be transformed, including partners, contractors and sub-organisations. A developmental tool for complexity management is then presented, based upon a framework capturing the factors identified by ATTAC managers as making their enterprise complex. It is proposed that this framework is used for discussion of complexities, leading to identification and removal of unnecessarily complex structures and hence lowering cost and focussing effort on complexities that are necessary to value creation. The section concludes with an exploration of the service aspirations and fears of the ATTAC contract stakeholders. For long term value to be co-created it is proposed that the entirety of the required service, including but not limited to the service explicitly described in the contract, is articulated. This section includes all three forms of transformation captured in the CIF.

Part II provides some of the foundations necessary for service contract development and delivery. Initial work identifies the capabilities required to co-create value within a ‘value-web’. Capabilities are mapped against core attributes of value co-creation. It is proposed that this matrix be used to define a firm’s service capability. The following chapter maps the major classes of uncertainty within service contracts against service delivery cost drivers. The resultant uncertainty-based cost framework provides information which may be used for service contract development and negotiation. A study of how incentives in service contracts impact upon organisational behaviour is presented. Service contract incentives encourage flexibility and adaptability, but this may contradict cost reduction objectives. Performance is dependent upon the customer and, therefore, incentive mechanisms may include customer performance. The section concludes with an analysis of the dependence of community level relationships upon successful service delivery. The work presents the transition observed in two contracts, from inter-personal relationships to community level relationships as the contracts matured. The section touches upon all three transformations as work covers capability, uncertainty of costing, incentives in contracts and relational governance.

Part III is focussed upon the challenges of transforming information. The section begins by introducing a model for the identification of service information requirements. Combining the aspects of service supply networks and service lifecycles, this 12-box model utilises a traffic light approach to signal how well current solutions address information requirements. The section continues with the analysis of how computer-based simulations play an important role in understanding trade-offs between service affordability and performance when developing service contracts. An application of discrete event simulation to service systems for complex engineering products is described. Finally a service information blueprint is introduced as a means of defining service contracts, processes and relationships between the two.

Part IV is product transformation focused. The work presented shows how products may be better managed for service provision, beginning by introducing service support solutions used by the UK MoD to deliver contracts for both availability and capability. An overview of techniques to plan equipment availability and maintenance is then given to raise awareness of techniques that may strengthen support solutions. This is followed by a piece of work focused on the applicability and implementation of predictive maintenance, providing details of combining prognostic modelling with Condition Based Maintenance (CBM) and how this may improve the repair and maintenance service provided for complex systems. The section continues with work on operational requirements for component replacement decision analysis and explores approaches to estimate maximum availability whilst preventing component failures. Research is then presented into delay time modelling that may be used to optimise maintenance service intervals with respect to specific criteria, such as system cost, downtime and reliability. Work using simulation methods to develop service procedures follows. This shows how simulated service operations may inform support outcomes in terms of learning, cost and process. A framework for the development of a Maintenance Dashboard is then proposed which delivers status information to stakeholders whilst an asset is 'active', aiding consistent decision making. In the concluding chapter of this section modernisation of platforms through the insertion of new technology is examined. This requires interaction between three principal stakeholders: acquisition authority; product-service system provider; and end-user. A transformation mapping approach has been developed which brings these three groups together to set their joint vision and plan activities.

The final section of the book, Part V, returns to explore in more detail the question we have begun to address in this chapter: how do we produce integrating frameworks that link together the different disciplinary areas required to deliver service?

It is noted that the transformation of people element of the CIF does not have a specific section within this book. Many of the sections contribute to knowledge in this area, but there is scope for further and more detailed work to be done. As further service type contracts are put out to tender, further work may focus upon the transformation of people, as they transform from a product to a service mindset.

Whilst the book reflects the work of a large number of academic and industrial contributors, it does not claim to provide the full picture of complex engineering service systems. Research in this area is ongoing and this book aims to set conceptual foundations upon which others can build. We seek to provide an overview and sufficient detail to engage the reader in the subject, both through the research done to date and in identifying the gaps and continuing questions. We hope our book represents a starting point for future researchers and practitioners engaging in the challenge of designing, delivering and evaluating Complex Engineering Service Systems.

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