Chapter 4
Complexity Management

Glenn Parry, Valerie Purchase and John Mills

Abstract This chapter explores the nature of complexity that arises in high value contracts between large organisations. To develop a framework, a detailed case study was undertaken to identify the factors that create complexity. The case studied was the availability contract to provide depth maintenance and upgrade on Tornado aircraft between BAE Systems and the MOD. The contract, named ATTAC, is worth ~£1.3bn and the MOD engaged with BAE Systems precisely to enable them to more cost effectively manage the complex enterprise of over 22 organisations or business units that deliver this service. The work explores the operation from a range of perspectives, interviewing managers from across the organisations involved. The factors contributing to complexity are described in context and a framework is presented which clusters them into six key areas. It is proposed that this framework may then be used as a tool for analysis and management of complexity.

4.1 Introduction

Service providers seek to enhance their value proposition and their competitiveness through improving customer's experience (Fitzsimmons and Fitzsimmons 2005). Value is realised not through the resources which create a value proposition, but by the value in use jointly created by the client and provider (Sandström 2008; Prahalad and Ramaswamy 2003). To deliver value in use, customers' experience becomes integral to the offering (Sampson and Froehle 2006; Heineke and Davis 2007). Servitised companies are faced with increased complexity as

G. Parry (✉) · V. Purchase · J. Mills
Bristol Business School, Frenchay Campus, University of the West of England, Bristol, UK
e-mail: glenn.parry@uwe.ac.uk

I. Ng et al. (eds.), *Complex Engineering Service Systems*, Decision Engineering,
DOI: 10.1007/978-0-85729-189-9_4, © Springer-Verlag London Limited 2011

Main Complexity factors	Product Groups	Process	Contracting	Organisation	Finance	People
Contributing Complexity factors	Variant	Dependency	Contract completeness	Enterprise boundaries	Financial regulation	Cultures
	Fleet	Recovery	Objectives	Geographic dispersion	Financial reporting	Customer
	Resource	Reporting	Risk	Structures	Cost	Leadership
	Technical	Governance	HR legal	Stakeholders		Line management
	Cross platform	Security	Regulations	Politics		Roles
				Partnering Constraints		Learning
						Transition management
Factor Level	Emergent or Deterministic?					

Fig. 4.1 Framework for complexity factors perceived by enterprise managers

customers move from deriving value from products to value derived from service experience (Kates and Galbraith 2007). The competence to deliver these experiences comes from skilful co-ordination of complex combinations of resources (Vargo and Lusch 2008). Yet complexity is an inhibitor to process improvement and hence the realisation of this value (Bateman and Rich 2003). We propose that recognition and identification of the drivers of complexity within a service enterprise will better enable managers to realise value, reducing complexity where possible.

As a first step, an approach to complexity identification and classification has been developed that forms the focus of the work undertaken for this chapter. The research is based on a case study of the availability contract to provide depth maintenance and upgrade service for Tornado aircraft between BAE Systems and the MOD, named ATTAC. Interviews with senior management were used to identify factors that contribute to complexity. A broad range of complexity elements were identified in the interview data. The elements that were identified as contributing to the complexity of the service were placed within a framework, Fig. 4.1.

The factors can all influence each other and cases could be made for most subfactors to be attributed under any lead heading. However, for the purposes of this analysis, the contributing factors were placed under the main complexity factor that best reflected the context being described in the specific interviews where that factor was raised. In some cases the context described spanned multiple main factors. We have grouped the contributing factors beneath the core factor that appeared most appropriate. Categorisation was pragmatic and has been developed to provide a starting point for organisational analysis and discussion. The factor level examines the unit of analysis—for example a product, process or service—displayed emergent behaviour, as a proxy for complexity, or was complicated but

gave outputs that were predetermined and thus not in itself complex. For example, operation of a single product may provide pre-determined output, but the operation of a number of products together may give rise to emergent complexity. This thinking is expanded within this chapter.

Whilst we can make no claim for generalisation, we would expect that the framework may be suitable as an initiator of analysis of complexity for many enterprises.

The chapter will be structured as follows:

- A brief overview of management complexity theory from the organisational and contractual perspectives
- A description of the case study approach used
- Identification of the elements of complexity for this service engineering support enterprise
- Discussion of potential application of the framework and opportunities for future work.

4.2 Complexity

What makes a business 'complex'? Complexity is difficult to define and measure (Foley 1996; Murmann 1994; Pighin 1998; Kim and Wilemon 2003; Schlick et al. 2007) and there appears often to be a resistance to provide clarification if it involves simplification (Elliot and Kiel 1997; Cilliers 1998). There are many definitions and perspectives, but here we seek only to present a condensed overview to provide understanding. Simple systems with small numbers of components, such as a pendulum, are well understood. Complicated systems, such as a jet aeroplane have many systems that interact through predefined rules (Perrow 1999). Complex systems have many systems that autonomously interact through rule sets that only emerge over time (Amaral and Uzzi 2007). Businesses are frequently managed as though they are either simple or complicated systems, being predictable, linear, measureable and controllable (Boulton and Allen 2007). The concept that businesses are somehow mechanical by nature has underpinned much of the approach to strategy and management development (Mintzberg 2002). This view is reinforced by the approaches and tools employed by managers e.g., standardisation, metrics, value stream maps. If businesses were so coherent in nature the role of the manager could be automated and growth could be assured. The experience of managers informs us that process outcomes are far from assured, as systems of people are usually complex and are only mechanical in nature under specific, stable circumstances (Boulton and Allen 2007). So how are complex systems characterised?

A complex system may be described as one made of a large number of interdependent parts which together, make up a whole that is interdependent within some larger environment with which resources are exchanged (Anderson 1999).

Complex systems are not deterministic; as part of natural phenomenon it is not possible to see the final outcome at the start as there are infinite possibilities (Kao 1997). Emergent phenomena develop as local interactions between agents alter their behaviour in response to each other (Bonabeau 2003). Cumulative local interactions build and shape group behaviour, but group behaviour may be separate and distinct from the behaviours of individuals. As such, systems that exhibit emergence may respond in counterintuitive ways (Youn et al. 2008). Emergence is formed in a 'bottom up' process and is used as a characteristic to classify systems as complex. It is proposed that complex systems can be modelled from the bottom up, simulating systems level behaviour by defining the distinct behaviours of numerous individual agents (Bonabeau 2003).

Boulton and Allen (2007) provide a set of key principles for complexity: there is more than one possible future; tipping points may occur, when systems tip due to seemingly unimportant events into new forms with potentially radically different characteristics; systems are interconnected and diverse and it is the diversity that permits change and creativity; local variation is a prerequisite for novelty as change happens within the micro-diversity, unpredicted from the situational 'average', yet potentially impacting the global enterprise; systems are emergent and co-evolving, with characteristics constantly changing with time; complexity does not mean chaos and helplessness, but managers must both plan for clear action based on best information and recognise that the best laid plans may give rise to unintended consequences, unexpected outcomes and remain flexible enough to react accordingly.

Pascale (1999) further divides complex systems into groupings and posits a subset of complex systems named complex adaptive systems [CAS] for which are provided four tests. First, there must be many agents acting in parallel. Second, there are multiple levels of organisation. Third, the system is subject to the laws of thermodynamics and must be replenished with energy to prevent it from slowing down. Fourth, pattern recognition is employed by the system to predict the future and learn—thus CAS can change or learn from its past (Pascale 1999). Beinhocker (1997) proposes that CAS have three characteristics: they are open and dynamic systems; they are made up of interacting agents; they exhibit emergence and self-organisation. CAS transition between points of equilibrium occurs through self organisation and environmental adaption. Order is said to be emergent, not predetermined, and mechanisms for controlling it must also be emergent (Dooley 1996). Many systems are complex (they meet some of the criteria), but not all are adaptive, meeting all of the criteria. Inherent in this approach is the concept of grouping different complex systems and the idea of some being more or less complex.

Applying complexity to business processes or project management raises challenges (Whitty and Maylor 2009). Managers must understand the system under control (Taylor and Tofts 2009), developing the ability to cope with both environmental change and changes in the task/customer requirement which requires organisational structures that are sufficient to provide control and flexible enough to adapt to local needs (Schuh et al. 2008).

Attempts have been made to understand the degree of complexity and design organisations to function accordingly in their environment. From an organisational theory perspective, Daft (2007) states that the more external factors that regularly influence an organisation and the greater the number of organisations in the domain, the greater the complexity. In the context of a production process it is proposed that complexity would be measured along three dimensions, giving three factors (Daft 1992). The vertical axis shows the number of levels in an organisation, on the horizontal is the number of departments or job titles and on the third axis is the spatial complexity, perhaps of different geographical locations. A second two-axis model proposed by Kates and Galbraith (2007) explores manufacture and integrated product and service providers, linking organisational form to complexity and defining the space for organisational design. Their model follows Galbraith's (2002) rationale of matching an organisation's design to the complexity of its environment. The X-axis of Kates and Galbriath's model is titled 'Product and Service Integration' and shows a spread offering from standalone product at the low end to an 'integrated system' at the high end. They describe integrated solutions with reference to an IBM offering, the design and installation of a new call centre comprising a range of hardware, software and staff training. The Y-axis of their model is labelled 'Complexity'. Their dimensions of complexity include the number of products, variety of products and customers, customer geographic distribution and degree of customisation offered. They provide a rule of thumb for product number; four or fewer do not add complexity, whereas 12 or more can add significant complexity.

Care must be taken over viewing the delivery of service from a single business unit perspective. A clear trend towards increasing specialisation among firms (Mills et al. 2004) has inevitably been accompanied by the emergence of notions like "Extended Enterprise" (Dyer 2000) and "service value networks" (Basole and Rouse 2008). While firms have always been a part of multiple networks, their dependence on other network members and hence their inability to fully control their output, has grown alongside or as a consequence of the narrowing scope of their competences. It may be salient to view the firm as a nexus of contracts that together delivers a service (Jensen and Meckling 1976) and explores how the nature of the contracts to deliver service may be an indicator of complexity.

The case study presented is based upon an availability contract (Ng and Ding 2010) for the servicing of fast jets, providing depth maintenance and upgrade, and is between two parties. The literature on contracting and economics discusses complexity and similarly presents factors that contribute to complexity. The degree of contract complexity might be measured by the degree of customisation of formal contracts and the requirement for considerable legal work (Macneil 1978). Additionally, a simple measure of contract complexity is indicated by the length of the contract (in pages), which previous work applied as an indicator of contract complexity (Joskow 1988; Popo and Zenger 2002). Eggleston et al. (2000) discuss contract complexity as a continuum and identify the three 'standard' factors contributing to contract complexity as: (1) rich in the expected number of payoff-relevant contingencies specified in the contract i.e., the contract assigns numerous different contingencies against

future possible outcomes. This covers obligations and entitlements; (2) variability in the magnitude of payoffs contracted to flow between parties i.e., contracts become more complex as the variability of payments increases under the specified contingency; and (3) severe in the cognitive load necessary to understand the contract i.e., the contract is difficult to understand and follow as the previous factors create a great number of permutations of potential outcomes, often spread across numerous annexes making prediction of future effects difficult. A contract is deemed 'complete', termed perfectly complete or 'p-complete' when it differentiates between all relevant future states. However, Eggleston et al. identify that this state is mainly theoretical and in most real world situations, due to factors such as a lack of trust, communication or unverifiable valuation, contracts are 'p-incomplete'. They may best achieve a state of being 'functionally complete', in which they are able to distinguish between states to the satisfaction of parties involved in a court. Faced with complex operations where futures are uncertain, contracts that provide that detail may fail to achieve even a functionally complete state. Longer contracts are more complete, but by necessity more complex. Eggleston et al. (2000) conclusions suggest detail may be sacrificed for the sake of simplicity, and suggest courts pay attention to the complexity of a contract when interpreting them.

From the research perspectives on complexity explored, we notice that findings and definitions from simple to complex are presented at a level of system aggregation selected by the authors to make their point (Perrow 1999; Cilliers 2000; Amaral and Uzzi 2007). All of these systems may be subject to further reductionism, yet the authors proposing them have taken a system, or system of systems approach and have taken the viewpoint of a pragmatic holist, even if they are of an in-principle reductionist viewpoint (Simon 1981), as they have chosen a level of abstraction that best illustrates the point they are wishing to make. In a search for understanding or solutions to a complex problem, the alternatives may be numerous holist approaches or reductionist approaches to make the problem faced simpler; the choice is made to best increase the chance of delivering a successful solution (Edmonds 1999).

To further explore how complexity may manifest and be usefully understood in relation to practice, we have undertaken case study research within an engineering service enterprise with the aim of identifying factors that contribute towards complexity.

4.3 Research Method

Pragmatically, we will follow Edmonds (1999) and argue that managers who are faced with complexity are fully able to identify it from their practical, experiential level of abstraction. Models of complexity are built upon the actions at the local level (Bonabeau 2003) and we propose that it is from the actor level that we may usefully identify characteristic drivers of complexity and explore the question of managing complexity in an enterprise.

We have chosen to proceed through a case study analysis (Yin 2003) and have focused upon the BAE Systems/MOD ATTAC contract which provides an availability service for the RAF Tornado aircraft. The particular case study was chosen for two main reasons—it was the first of its scale and complexity between the Provider and the Client. Second, though both parties intended to continue to let and bid for such contracts this first attempt was an opportunity for both parties to learn, which enabled the researchers to gain access to both client and provider and interview widely at the senior management level. Interviews were conducted face-to-face; 6 Client and 22 Provider interviews were undertaken with key managers from across the enterprise. Interviews were recorded then transcribed. The interviews were semi-structured at an average of 1.5 h per interview though some were considerably longer. They were conducted in 2008.

The interview transcripts were initially codified against the questionnaire and analysed to identify common responses and provide credence to findings whilst qualitative ethnographic analysis was employed to explore content (Bryman 2004). Further data content analysis followed a category scheme, deductively derived from the answers provided (Weber 1990). Three coders were used to ensure a degree of agreement among coders (Weber 1990). Participants were anonymous during analysis in an attempt to remove any bias and at the request of participants themselves (Seale et al. 2004). The anonymous results were presented back to managers who validated the findings.

The analysis of the interviews by the three coders identified 258 different quotations that referred to elements that made the service enterprise complex. The coders then examined these quotations and extracted the specific factor(s) that created the complexity. This analysis requires some interpretation but was repeated for all the quotations using three coders, meeting during workshops over 6 months to provide consensus in analysis and agreement of the emergent inductively derived categories. The resultant sets of data were analysed for duplication of factors. Thirty-eight different complexity factors were identified. Analysis of the factors and the context from which they were derived allowed them to be grouped into 6 core categories with 31 sub-categories and a factor level challenge to test if the unit of analysis displayed emergent behaviour or was complicated but predetermined. It was recognised that there was opportunity to place many of the sub-categories under a number of core categories, but pragmatically they are placed under a single core category which was found to best illustrate their context. The analysis presented in the chapter has been rigorously validated through a series of presentations to key customer and provider contract and support functions. Written reports have also been made available for validation and feedback (Yin 2003).

We shall now present the core and supporting complexities factors as perceived and described by the interviewees.

4.4 Factors Contributing to Complexity

Each factor as perceived by interviewees has been identified and coded during analysis. These factors are presented here in context of their description.

4.4.1 Product Groups

In the case example the product being studied is a fast jet, in particular the RAF Tornado aircraft. This is a complicated product as it is made up of a large number of other products. Individual components may form units, which combine to form systems. The authors contend that similar variant examples of the aircraft when new could not be described as complex as they were repeatable, predictable and any failure of the higher systems is subject to diagnosis by analysis through reduction. As the individual aircraft is no-longer new and has been serviced and modified numerous times, each aircraft has become unique with regard to its operation and service history and its future performance and service requirement is likely to vary accordingly. Aircrafts have increased variance which may cause issues for servicing operations when making changes to systems or components, perhaps giving rise to emergent behaviour, but individually each aircraft product could still not be described as complex. When observed as a group or operating as a fleet, we may see this individuality leading to complexity.

The product originally existed in a small number of different production variants, with later modifications made to individual aircraft according to intended use. There were originally three basic product variants: a fighter bomber, a reconnaissance aircraft and an interceptor. The product variants were subject to mid-life upgrade, which modified the entire fleet. As the aircraft were bought by four different nations, each nation also had its own variants. These factors add to the product variance contributing to potential fleet complexity.

The RAF Tornado aircraft are described as a fleet, but they are operated as numerous ‘fleets within fleets’. The 139 strong RAF Tornado fleet is currently modified to a number of varying standards, giving rise to 20 different aircraft clusters which have similar attributes that make up seven fleets (National Audit Office pp. 31, 2007). The various operational aircraft are equipped for their required mission. A number are ‘front line’ aircraft and may at any one point be equipped with a number of different weapon and sensor equipment. Some are trainer aircraft and will be modified according to the current training requirement.

The resources that were employed to construct the aircraft are geographically diverse, both nationally and internationally as the aircraft was manufactured by Panavia, a tri-national consortium (UK, Germany and Italy) formed and owned by BAE Systems, MBB (Now EADS) and Alenia. Each country made a significant contribution to the manufacture of major parts of the aircraft. In addition, numerous sub-contracts were given to companies to produce systems, sub-systems and components.

A swing-wing fast jet such as the Tornado is demanding and complicated as a piece of engineering. The multitude of interfaces, where the integration of the numerous sub-systems from different suppliers, coupled with the varying states of modification for each aircraft, may introduce technical complexity.

To reduce the possibility of complexity becoming a significant factor for the aircraft as a product group, an upgrade programme is currently underway to reset the fleet configuration to seven common clusters. More broadly a number of components and systems are common across a number of platforms (aircraft and other military equipment including ground vehicles etc.). This adds to its robustness and supportability during operation.

4.4.2 Process

The process of supporting the availability of the product is challenging. The prime contractor, BAE Systems, is a large manufacturing company and is able to operate successfully because of its process rigour. To deliver availability in this contract, the high level processes are partnered between the RAF and BAE Systems—two large organisations which operate many processes that need to integrate at various levels to deliver the availability levels required in the ATTAC contract. This can lead to situations where processes are duplicated, incompatible or require sign off from multiple parties which introduces bottlenecks. Also, many processes operate deep within the organisations that impact upon the ATTAC contract, but do not have line of sight to the operations. There may be many interfaces between the process and front line operations and this loss of line of sight was highlighted as leading to process complexity.

Many different process dependencies and interdependencies exist. The process integration across multiple organisations in the enterprise created complexity due to the dependency they had upon each other for the successful delivery of the contracted service. The value that each individual placed upon a particular aspect of the process frequently differed according to the value the party realised from the transaction, creating imbalances in the dependencies.

Process rigour and standard operating procedures were also difficult to stabilise due to emergent issues in the service requirement. Instances of emergent processes included ‘unplanned parts requirements’ and the need for completely new processes to be developed as some parts “*simply had never been bought before as spares*”. These issues introduced new, unknown lead times to processes, placing a demand on all parties within the service enterprise to have process flexibility.

Such flexibility leads to a requirement for processes of recovery that may well be constructed ‘ad hoc’ locally by individuals. Recovery consumes resource and is an additional activity to the main planned enterprise processes. Whilst some recovery actions may be planned for, through its nature it remains fundamentally unplanned and may drive complexity as a factor affecting processes.

Data reporting processes e.g., performance metrics, costing etc. in multi-organisational enterprises may have been developed from different contexts and different requirements. This may lead to a multiplicity of data requirements from processes in operation. Some of these requirements, in this case due to both the military and aviation contexts, may be legally binding and require specific methods or signatures. Others may add no true value to the business and should be halted.

Many are fed into corporate or public governance structures as proxy-monitors of system performance. Compliance with governance requirements, public sector and corporate in this case, took up a great deal of time, added to the workload and complexity of management. Governance reporting may include data that are legally required and both understanding the requirement and legal standing of a request increased the complexity of process management.

Data and equipment that flows through the processes may also mean additional security measures are required. Restricted data such as software code, product detail or the service record for an aircraft may not be freely transmitted or displayed in a multi-organisational enterprise where not all the actors have sufficient security clearance. Weapon systems or the aircraft canopy and the ejector seats which contain explosive charges also place security restriction and impact upon the processes. This restriction on the free flow of data between parties significantly complicates processes. It also creates additional issues where it may not be possible to share data that would otherwise be useful. These restrictions to communication drive local behaviours which may give rise to unintended systems level outcomes, a core element of complexity.

4.4.3 Contracting

ATTAC, as multi-organisational enterprise that has a contract to deliver fast jet availability, has a complex contract that is between the primary contractor, BAE Systems and the client, MOD. Availability contracts deliver an agreed number of aircraft or engines at an agreed level of capability over the length of the deal. The ATTAC contract for Tornado is for availability of the aircraft, not the engines, though these are obviously a major dependence. This is a separate contract named ROCET and is held by Rolls-Royce Plc. Whilst the contract will have a number of companies named within it, there will also be a number of companies that have process dependencies that are not named on the contract (Mills et al. 2010).

The ATTAC contract is described as "*three and a half feet high*", which, allowing for colloquial exaggeration, would indicate that it is complex by the definitions of contract complexity (Macneil 1978; Joskow 1988; Popo and Zenger 2002; Eggleston et al. 2000).

The contract length is a direct result of a desire by the government to cover all the possible eventualities and create a functionally (f)-complete contract. However, due to the nature of service offered, approaching this task in this way is not

feasible at the outset and could not be achieved at least until the enterprise has been in operation for a number of years and the processes and outcomes are established. Therefore the current contract may be described as not (n)-complete and complex by the measures of Eggleston et al. (2000).

A key driver of the contract length is risk. Each party had the desire to minimise risk to their institution and ensure that they are compensated for the risk that they take on. The organisations also tried to ensure that risk was bounded so that any liabilities will be limited. It was also important for the MOD not to transfer too much risk and jeopardise the future of the commercial organisations.

Within this partnered enterprise there is a minimum requirement for 50% of the personnel on the production line to be RAF and the other 50% may be from industry. This creates a situation where two people working together on the same job may be on completely different contracts with differing incentive structures. Local individual agent interaction may lead this to be a cause tension, potentially driving behaviours that create complexity systems level. It also makes the management of HR contracting more difficult as individuals seek to interpret their terms against others and equalise their conditions.

During interviews, the contract was described as being "*owned by lots of different people with different objectives*". The objectives written into the contract for the prime contractor are many but the enterprise partners may change their objectives over time, leading to either a conflict between contract and desired objectives or a requirement to change the contract. The number of contract changes made was described by one interviewee as *"absolutely enormous"*. The multitude of objectives and changing needs also creates a tension for the prime contractor between the need to be customer focused and the need to be delivery focused.

4.4.4 Organisation

Whilst ATTAC was a novel contract which created a new way of interacting between partners, the larger surrounding organisational constraints were not changed to facilitate its operation. The enterprise that delivers the ATTAC contract is a complex organisation existing of over 30 different entities, both public and private, on and off base. Whilst the contract represents a significant sum of tax payer's money, approximately £1.3 billion, it is only a small percentage of the total financial streams managed by the two main parties, MOD and BAE Systems. These organisations co-create the value for ATTAC through servicing Tornado aircraft on base, primarily at Marham, but both have vast 'back office' support structures that directly and indirectly affect the operation.

This multi-organisational service enterprise creates a challenge in the identification and definition of a functional organisational boundary. Some form of definition is necessary for the organisational managers to understand and operate within, though it is recognised that this boundary will need be flexible and likely to constantly change.

The clarity of organisation structure that delivers the contract is lacking as it is difficult to conceptualise the numerous different entities that work together to deliver the service and there are currently few suitable tools (Mills et al. 2009a). This makes communication of organisational structure difficult and hence new managers are challenged to understand the structures that they are faced with managing.

Both main signatories to the contract also make extensive use of acronyms in their organisational structures. Such acronyms refer to semi-autonomous business units within both provider and customer organisations. Many struggled to remember what each acronym stood for. Adding further complication to gaining understanding is the often misleading business names that the various companies, business units or operations have. Even when known, both organisations are constantly in a state of flux and the individual units moved, renamed or shut down completely. This is a significant issue particularly for this organisation, as much organisational knowledge is lost because there is a frequent turnover of staff due to the 3-year rotation of military staff through the base.

Geographic dispersion adds complexity to the enterprise. The RAF has Tornado service at both Marham and smaller operations at Lossiemouth. The RAF Tornado support management team is located in RAF Wyton whilst MOD's procurement arm within DE&S is located in Bristol, the Defence Storage and Distribution Agency [DSDA] holds some of the parts in Germany, Panavia is an international organisation that was originally formed to build the aircraft and is a co-ordinator for many of the aircraft spares, and the RAF Head Quarters is in High Wycombe. BAE Systems have a similar operational spread.

Within and operating across the various organisations are management structures. During the initial transition to ATTAC implementation, many of these structures were mirrored MOD/BAE Systems structures to facilitate communication, though this can lead to many agents acting in parallel. There are further complications with the organisational and managing structures as we explored its supply chain management. The RAF operates a number of different aircraft that have commonality, if not directly in line replaceable units, then in the companies that supply them. A number of RAF integrated product teams [IPTs] were created to manage these parts or systems across the various platforms operated. Many of these were 'wrapped up' when the ATTAC project began. However, a number remain and the parts supply management for Tornado may be a very small part of their activity. Since they are not a signatory for the contract, this can potentially create further management challenges through diverse and potentially conflicting intra- and inter-organisational priorities.

This challenge also raises the issue of stakeholder complexity. The operational squadrons are the primary stakeholders in so far as they are the aircraft users. However, they are not the budget holders. Moving away from base there are numerous other public sector stakeholder organisations within the RAF such as Air Command—the RAF HQ, but also non-RAF organisations such as Defence Estates who provide the hangars, Defence Equipment and Support (DE&S) which equips and supports the UK's armed forces, the Treasury and ultimately Parliament. Within the private sector the contract is primarily run by BAE Systems MAS

[Military Air Solutions], who rely upon numerous BAE Systems organisations such as HR, purchasing and engineering support functions and are ultimately accountable to the BAE Systems board of directors and shareholders, many of whom do not have 'line of sight' to the service operation.

Political challenges arise as these stakeholders do not represent simple relationships. Key decision makers are frequently far removed from the front line operations. Decisions made in the UK Parliament around Treasury spending on the armed forces or decisions to go to war directly impact upon the service operation.

The partnering aspect of the contract was recognised as a key success factor. The nature of relationships between the partners, traditionally adversarial, has changed to a more co-operative service nature and this is influencing the organisation.

A key element is the shared resources. BAE Systems operates its service operation in an RAF hangar on an RAF base with 50% of their staff working on the aircraft. As stated before, there are a large number of other contributing organisations. However, legally the RAF cannot be a partner with business and they must 'own' the aircraft. There are also few options for finding alternative customers or suppliers. All these issues create organisational constraints.

4.4.5 Finance

The finances for the enterprise were organised to be, at least notionally, simpler through the use of an availability contract as opposed to a list of spares provision. However, the finances are difficult to manage due to the complexity of the enterprise, which in turn makes modelling and forecasting the cost of service difficult. Budgeted risk cost is available to facilitate planning, but is very difficult to access. It is also difficult for managers to put money aside in their budgets as deferred spend since there is a potential double penalty as unspent monies may be taken back and the overall budget may be reduced by that amount the following year. The budgets are controlled by a number of top level budget holders who are influential but many of whom may not be part of the contract, or even aware of the detail of the ATTAC contract.

The complexity of financial reporting is affected by contributing factors from process, contract and organisation. The challenge of appropriate enterprise integration goes beyond the budgeting and into their financial systems. Organisational units within the ATTAC enterprise use different operational and financial software systems which 'do not talk to each other'. They often have different processes and stakeholders.

Internally, the company has to attribute overheads to their staff which makes them appear expensive in comparison to subcontract labour. However, in 'real' terms, this is not the case.

Financial reporting regulations also add to the complexity. As the government is the customer of the service, there is no national taxation to pay. However, as the work is undertaken by industry, the government customer pays tax which it must

then claim back. This creates additional financial processes which are non-value adding activity.

These processes all take up the time of the managers engaged in delivering the service and create a time lag between requirement and funding. To deliver the required service to the squadron in a timely manner the managers on both sides had to carry short-term financial risk, effectively outside of contract and without commercial cover, in order to ensure that aircraft were modified or serviced correctly and available.

Financial reporting from the partnered organisation is therefore complex and made more challenging by potential political pressures applied if the budgets are either under or overspent. This influences behaviour across and beyond the enterprise, though the understanding remains that the service should be delivering best value to the taxpayer.

The service is constantly under cost pressure. The availability contracts, including ATTAC were created as part of a cost reduction initiative by the MOD and Defence Logistics Organisation.[1] There is an underlying assumption that there will be a cost reduction year on year from the service operation—though this seems to be in contradiction to the increased demand being placed upon personnel due to the number of conflicts that the UK is involved in.

4.4.6 People

A large number of people are directly and indirectly involved in the ATTAC contract and it is the people who enable the complex service described so far to operate successfully. Collaborative process design by all stakeholders has helped reduce complexity.

Organisational cultures are strong across all the partners and this influences agents, process management and outcomes. The RAF develops specific cultures as part of its operations and BAE Systems has a distinct business culture. The various operational sites for all the partners also have specific sub-cultures. The cultural aspects of the business were described in both positive and negative terms. In the early stages of contract implementation, when problems were encountered the groups 'retreated' to their positions, making cross-cultural working difficult. Problems were attributed to 'working with civilians' or to customers failing to deliver necessary support. At later stages of contract implementation, the 'on base' partnered service has developed its own culture, including a strong sense of having a shared objective and this has enabled the contract to become functional.

[1] From 1 April 2007, the Defence Logistics Organisation ceased to exist and Defence Equipment and Support was established to manage all equipment throughout its life, from acquisition to disposal.

The 'customer' that the enterprise creates value for is difficult to define as there are so many different stakeholders. The final customer is the pilot of the aircraft, but they are not budget holders. They are part of a squadron, another customer, whose operational activity is controlled by fleet planning, RAF Air Command, the MOD, Treasury and Government respectively. But the contract was between DLO, subsequently reorganised into DE&S, and the service and operation of the aircraft is directed by ILOC, the Tornado and Logistics Operating Centre, all of whom may also be recognised as a primary customer. There is an additional complexity in that, as this is a partnered arrangement where value is co-created, BAE Systems and the other providers of government assets may also be seen as 'customers'. In this context the term 'customer' begins to lose its meaning, though it is still very much in use. The authors highlight that great care needs to be exercised when using or engaging in discussion of customer and clarity should be sought on what exactly is meant.

The ATTAC contract has been discussed in terms of a partnered enterprise, but is made up of individual organisational units, staffed by individuals from one or possibly from a number of differing organisational cultures. For example, the hangar activity is undertaken by a mixture of civil and military personnel with very different cultural employer perspectives shaping their behaviour. With regard to leadership, we found that each of the organisations had leaders for ATTAC located within their management teams. The leaders managed their organisations contribution and also managed their interactions with the other organisations. Consistency of leadership can therefore be a problem both in terms of diverse objectives and more literally as personnel change over time. Managing the programme requires close relationships among the organisational leaders which is difficult to maintain due to rotation of staff.

The blurring of the organisational boundaries, with people from different organisations working side by side on the same job on site means that line management is more challenging. Military personnel may find themselves reporting to a business manager and vice versa. This may also reinforce cultural complexities as traditionally the RAF managers play a much greater role in the life and career management of their personnel, ensuring that they have broad experience but also that their families are looked after. This is in contrast to private enterprise where individuals play a much more active role in planning and managing their own career progression and would not expect any management interest in their family circumstances.

Roles that both the organisations and the people in the enterprise must undertake to deliver the service have changed considerably due to the nature of the ATTAC enterprise. Some of the roles are different as BAE Systems no longer sell the RAF an aircraft, but instead work alongside them to deliver a service to the front line squadrons. This changes the nature of some of the managers roles as they are intimately engaged with operations and constantly faced with the 'customers' personnel. Their role requires greater flexibility as much of their work requirement will be emergent as the value is co-created in the repair hangar. However, further back in the organisations, away from the customer/supplier contact points many of

the managers' work requirements will appear to be the same. Functional managers and staff who provide support for service contracts may therefore be unaware of the changing business model within which they operate. This can also create added complexities as behaviours and decision making may not align with new business models.

Learning and recognition of change is required in many areas as the enterprise transforms from a product-driven buyer-to-supplier relationship to an enterprise that understands how complex engineering services are co-managed and co-delivered. The differences and similarities between products and services and their management need to be clearly understood by all parties. Likewise all enterprise parties need to learn how to most effectively implement the new requirements in this interdependent environment. The lessons learnt during the development and adoption of the ATTAC contract must also be captured and disseminated so that when future contracts are available, the enterprise can more rapidly and cost effectively develop.

Complexities were also attributed to the learning process necessary in contract implementation. The learning process will be ongoing; will require constant reinforcement and need to be an embedded part of the structure due to the rotation of staff, both in the private and public sector.

Transition Management is a constant challenge within this case study. The number of different businesses and departments and the seemingly constant change or reorganisation they undergo is a significant complexity. The move from product- to service-based contracts also brings in a significant number of new concepts to these groups, not least 'partnering to co-create value'. The ATTAC contract is only one of many different programmes that drive change initiatives which impact upon the enterprise including site closures, relocation and the introduction of Lean process improvement techniques.

The ATTAC contract is the latest contract development from the MOD and it is expected that in the future an increasing number of higher value contracts will be offered for partnered delivery. It is critical therefore that the service enterprise partners learn to effectively manage the organisational transition process. It should be noted that whilst transition may reach a point of equilibrium, there will be no recognised end to the process.

4.4.7 Emergent or Pre-determined

From the findings it would appear that the level of analysis may define whether a factor is complex and may exhibit emergent behaviour, or complicated with predetermined output that potentially contributes to higher level emergence. The behaviour of local agents shapes the behaviour of the whole system, but that systems level may be independent of individual action. For example, a single service operation undertaken on the aircraft may be described as complicated, but it would be difficult to make any case for it being complex. All of the different service operations have been detailed and captured in text, along with approximate

times in which they may be completed, leading to single operations seemingly having pre-determined outcomes. However, further issues may arise when undertaking service and upgrade involving multiple processes that may necessarily create changes in priority and hence create changes to planned operations. It is the behaviour of local agents appropriately interacting and reacting when dealing with arising requirements that combines to create emergent complexity. Management are to question if a unit of analysis (process, system etc. being examined) exhibits complexity as the outputs are emergent or is complicated representing output of a predetermined system.

4.5 Using the Complexity Factor Framework

The ATTAC case has been presented as an example of a complex enterprise. Following interviews and detailed analysis the factors identified as potentially contributing towards complexity were placed within the framework shown in Fig. 4.1. Six core categories, 31 sub-categories and a factor level challenge were identified. Sub-categories were pragmatically placed beneath the core category that best reflected the context in which it was raised—though it is recognised that many subcategories may be relevant to a number of core categories.

It was widely recognised during interviews that many of the factors that add to complexity were not a result of customer requirement, but rather bureaucracy or historic precedence. As such, the generated complexity introduces time and cost. The method for application of the framework forms part of ongoing research with the enterprise and is currently being assessed as a basis for analysis of organisational change through reduction in complexity.

Each factor within the framework may be discussed with reference to a specific context using a three-factor analysis of complexity value, based on the groupings for waste from the Toyota Production System (Ohno 1988). First, those factors that add to the complexity of the systems that are non-value adding and can be immediately eliminated. Second, those factors that are currently embedded in process, equipment, contract or other legal frameworks and must be identified and strategies developed to remove or minimise their impact over a managed time period. Third and perhaps most important, those factors of complexity that create value and profit, embodying the reason that the company has been engaged to act due to its competency in managing these factors.

Each factor is discussed by a management team within their context—does the factor manifest in their operations and how does the factor affect them? Is there sufficient evidence to support their responses and if not, how may this be gathered? What plans are in place to act? Should the factor be applied to sub-processes and each explored separately? These factors are assigned a red/amber/green status in the framework to facilitate the identification and application of scarce resource upon the issues that are deemed in need of most direct attention. At the time of writing, practical application of this framework is ongoing.

4.6 Conclusions and Future Work

Pragmatically, we have taken complexity of a service enterprise to be defined from the actor's perspective, identifying factors that may lead to complexity via a qualitative case study using semi-structured interviews. The set of complexity factors that result are a product of the respondent's interpretations of their context. Thus the generated complexity and complex adaption described use a set of criteria defined by the interviewees, with complexity taken to be from their proposed level of abstraction (enterprise, system, component etc.). Whilst the identified six core, 31 supporting complexity factors and factor level challenge significantly exceed the three factors for complexity of an organisation proposed by Daft (1992), we find that the factors within the framework are supported by the general meanings of complexity found in the literature.

The case study draws upon the complexity of the enterprise that delivers the ATTAC contract, explored through the 'perceived' complexities identified in interviews with managers across the enterprise. The case is presented as an example of a complex service contract and the MOD engaged with BAE Systems precisely to enable them to better manage the complex enterprise which delivers the service. The meanings of the answers given to the question of complexity have been interpreted by the researchers, but by using three different researchers we have sought to minimise any bias. The factors presented represent a substantial analysis of our findings, but we make no claim for identification of a comprehensive set of factors that represent the true scale of complexity of the case study contract. By grouping into a factor framework we have further proposed a tool for managers to analyse their enterprise based on complexity, such that time and cost may be reduced. This tool is developmental at the time of writing. However, knowledge and understanding of the complex service delivered by the enterprise is still developing and it is expected that there will be further changes to the factor framework and guidance on its application as a tool for complexity management.

4.7 Chapter Summary Questions

Complexity obfuscates and introduces cost and may exceed that which is inherently needed to perform the service task. We provide a framework of complexities identified by managers that may be used to discuss and identify strategies for complexity management and cost reduction.

- Is our assumption that costs relate to complexity valid in your experience?
- What are the inherent complexities which are part of the job and what are created unnecessarily?
- Are plans in place to reduce unnecessary complexity—both over the short and longer term?

Acknowledgement. The authors would like to acknowledge and thank their sponsors within BAE Systems, Louise Wallwork and Jenny Cridland, and especially John Barrie for his support and direction. We would also like to thank the ATTAC team from both BAE Systems and RAF/MOD for their full engagement with our work. This research was supported by BAE Systems and the UK Engineering and Physical Sciences Research Council via the S4T project.

References

L.A.N. Amaral, B. Uzzi, A new paradigm for the integrative study of management. Physical and technological systems. Manag. Sci. **53**(7), 1033–1035 (2007)

P. Anderson, Applications of complexity theory to organizational science. Org. Sci. **10**(3), 216–232 (1999)

R.C. Basole, W.B. Rouse, Complexity of service value networks: conceptualization and empirical investigation. IBM Syst. J. **47**(1), 53–70 (2008)

N. Bateman, N. Rich, Companies' perceptions of inhibitors and enablers for process improvement activities. Int. J. Oper. Prod. Manag. **23**(2), 185–199 (2003)

E.D. Beinhocker, Strategy at the edge of chaos. McKinsey Q. **1**, 25–39 (1997)

E. Bonabeau, Predicting the Unpredictable. Harv Bus Rev **80**(3), 109–116 (2002)

J. Boulton, P. Allen, Complexity perspective, in *Advanced strategic management: A multi-perspective approach*, vol. 14, 2nd edn., ed. by M. Jenkins, V. Ambrosini, N. Collier (Palgrave Macmillan, Hampshire, 2007), pp. 215–234

A. Bryman, *Social research methods*, 2nd edn. (Oxford University Press, Oxford, 2004)

P. Cilliers, *Complexity and postmodernism: Understanding complex systems* (Routledge, London, 1998)

P. Cilliers, What can we learn from a theory of complexity? Emergence **2**(1), 23–33 (2000)

R.L. Daft, *Organisational theory and design* (West Publishing, St. Paul, 1992)

R.L. Daft, *Understanding the theory and design of organisations* (Thomson South-Western, Mason, 2007)

K. Dooley, A nominal definition of complex adaptive systems. Chaos Netw **8**(1), 2–3 (1996)

J.H. Dyer, *Collaborative advantage: Winning through extended enterprise supplier networks* (Oxford University Press, Oxford, 2000)

B. Edmonds, Pragmatic holism (or pragmatic reductionism). Found. Sci. **4**, 57–82 (1999)

K. Eggleston, E.A. Posner, R.J. Zeckhauser, Simplicity and complexity in contracts. John M. Olin Program in Law and Economics Working Paper No. 93, University of Chicago Law School. doi: 10.2139/ssrn.10.2139/ssrn.205391, 2000

E. Elliot, L.D. Kiel, Nonlinear dynamics, complexity and public policy: Use, misuse, and applicability, in *Chaos, complexity and sociology: Myths models and theories*, ed. by R.A. Eve, S. Horsfall, E.L. Lee (Sage, London, 1997)

J. Fitzsimmons, M. Fitzsimmons, *Service management: Operations, strategy, and information technology* (McGraw-Hill/Irwin, New York, 2005)

D.K. Foley, *Barriers and bounds to rationality: Essays on economic complexity and dynamics in interactive systems* (Princeton University Press, New Jersey, 1996)

J. Galbraith, *Designing complex organisations* (Addison Wesley, Reading, 2002)

J. Heineke, M. Davis, The emergence of service operations management as an academic discipline. J. Oper. Manag. **25**, 364–374 (2007)

M.C. Jensen, W.H. Meckling, Theory of the firm: Managerial behavior, agency costs and ownership structure. J. Financial Econ. **3**(4), 305–360 (1976)

P. Joskow, Asset specificity and the structure of vertical relationships: Empirical evidence. J. Law Econ. Organ **4**(1), 95–117 (1988)

J. Kao, *Jamming: The art and discipline of business creativity* (Harper Collins, New York, 1997)

A. Kates, J.R. Galbraith, *Designing your organization* (Wiley, New York, 2007)

J. Kim, D. Wilemon, Sources and assessment of complexity in NPD projects. R&D Manag. **33**(1), 15–30 (2003)
I.R. Macneil, Contracts: Adjustment of long-term economic relations under classical, neoclassical and relational contract law. Northwest. Univ. Law Rev. **72**, 854–905 (1978)
J.F. Mills, J. Schmitz, G.D.M. Frizelle, A strategic review of supply networks. Int. J. Oper. Prod. Manag. **24**(10), 1012–1036 (2004)
J. Mills, V. Crute, G. Parry, Enterprise imaging: Visualising the scope and complexity of large scale services. QUIS 11—The service conference, June 11–14, Wolfsburg Germany, 2009
J. Mills, G. Parry, V. Purchase, Public sector out-sourcing: Understanding the client's aspirations and fears. Proceedings of the 11th International La Londe Conference in Service Management, May 25–28 (The Institut d'Administration des Entreprises (IAE), La Londe Les Maures, France, 2010)
H. Mintzberg, *The strategy safari* (Prentice Hall, Harlow, 2002)
P.A. Murmann, Expected development time reductions in the German mechanical engineering industry. J. Prod. Innov. Manag. **11**(3), 236–252 (1994)
National Audit Office, Transforming logistics support for fast jets. Available at: http://www.nao.org.uk/publications/nao_reports/06-07/0607825.pdf. Accessed Feb 2010 (2007)
Ng I, Ding X, Outcome based contract performance and co-production in B2B maintenance and repair service. Dept of Management Discussion Paper Series, University of Exeter, 2010
T. Ohno, *Toyota production system: Beyond large-scale production* (Productivity Press, New York, 1988)
R.T. Pascale, Surfing the edge of chaos. Sloan Manag. Rev. **40**(3), 83–94 (1999)
C. Perrow, *Normal accidents: Living with high risk technologies* (Princeton University Press, NJ, 1999)
M. Pighin, An empirical quality measure based on complexity values. Inf. Softw. Technol. **40**(14), 861–864 (1998)
L. Poppo, T. Zegner, Do formal contracts and relational governance function as substitutes or complements? Strateg. Manag. J. **23**(8), 707–725 (2002)
C.K. Prahalad, V. Ramaswamy, The new frontier of experience innovation. MIT Sloan Manag. Rev. **44**(4), 12–18 (2003)
S. Sandström, B. Edvardsson, P. Kristensson, P. Magnusson, Value in use through service experience. Manag Serv Qual 18(2), 112-126 (2008)
S.E. Sampson, C.M. Froehle, Foundations and implications of a proposed unified services theory. Prod. Oper. Manag. **15**(2), 329–343 (2006)
C. Schlick, E. Beutner, S. Duckwitz, T. Licht, A complexity measure for new product development projects. Proceedings of the 19th international engineering management conference 2007 (IEEE Publishing, Austin, 2007), pp. 143–150
G. Schuh, A. Sauer, S. Doering, Managing complexity in industrial collaborations. Int. J. Prod. Res. **46**(9), 2485–2498 (2008)
C. Seale, G. Gobo, J.F. Gubrium, D. Siverman, *Qualitative research practice* (Sage, Thousand Oaks, 2004)
H.A. Simon, in *The architecture of complexity*. The sciences of the artificial (MIT Press, Cambridge, 1981), pp. 192–229
R. Taylor, C. Tofts, *Managing complex service systems* (Springer, New York, 2009)
S.L. Vargo, R.F.L. Lusch, Service-dominant logic: Continuing the evolution. J. Acad. Mark. Sci. **36**(1), 1–10 (2008)
R.P. Weber, *Basic content analysis* (Newbury Park, CA, 1990)
J. Whitty, H. Maylor, And then came complex project management (revisited). Int. J. Proj. Manag. **27**(3), 304–310 (2009)
R.K. Yin, *Case study research: Design and methods*, 3rd edn. (Sage, Thousand Oaks, 2003)
H. Youn, H. Jeong, M. Gastner, The price of anarchy in transportation networks: Efficiency and optimality control. Phys. Rev. Lett. 101(12). doi: 10.1103/PhysRevLett.101.128701, 2008