# Chapter 28
# Defence Support Services for the Royal Navy: The Context of Spares Contracts

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**Abstract** "Defence Support Services" (DS2) for the Royal Navy are a particular form of "Product-Service Systems" (PSS). PSS deliver on a turn-key basis equipment/system with related spare parts, training and upgrades to the Royal Navy. In order to stimulate and reward the DS2 provider to improve its services and performance, the Royal Navy wants to shift its contracts from "traditional spare part deliveries" to "performance based contracts" such as "Contracting for Availability" (CfA). However, it has been observed that cost wise, CfA is not logical for all types of complex engineering projects. CfA typically faces higher risks and uncertainties from the solution provider in the early phases of the life cycle (e.g. design phase). There are difficulties in projecting the future costs and required resources in the bidding stage of the contract for the service provider e.g. Obsolescence and required trained workforce for a new introduced technology. These aspects have led some practitioners to prefer spare parts based contracts rather than adopting CfA. However, spare part contracts also have challenges, such as the service provider may not be responsible for the end-to-end process of delivering the support service, and limited time and penalties can cause issues for delivering the service. Moreover, given an extended number of possible solutions, support service providers need an insight from different parts of the supply chain about the cost and time perspectives. This chapter contributes by presenting two novel solutions in spares based contracts including a process to trade-off between time and cost across the supply chain and a framework to assess the costs and benefits of applying "Additive Manufacturing" in the front-end of a DS2 system. Lead time and overall cost are the two main dependent variables across the supply chain. Minimising them lead to a better service delivery. However, there are some challenges for minimising the lead time and overall cost in the supply chain.

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## 28.1 Introduction to Servitization and Spare Part Contracts

Servitisation is a transformation path for the manufacturing field to develop the capacities to offer and provide services as a supplement to their traditional product offerings. Servitisation is a conventional solution which is growing more in the context of supplement offering services all around the world as well as in the UK [1–3].

Due to market demand, for providing and delivering supplementary and individuals services in different sectors. Several processes and various types of support contracts have been introduced, offered and applied as the solutions for industries. Spare part contracts as part of a servitisation process has been introduced, developed and implemented in the last years and the Royal Navy might be considered as one of the main clients for this type of contracts. For the proposed type of contracts, a service provider delivers support services in order to maintain assets at the desired performance level in the context of the conditions set by the asset owner [4]. The Ministry of Defence (MoD) has introduced three types of spare part contracts regarding their demands. Initial type called "Spares Inclusive Upkeep (SIU)"; in the SIU Industry is contracted for the supply of assets along with the maintenance of spares whilst MOD is still responsible for mending equipment personnel, facilities and technology wise. The second type of spare contracts "Incentivised Upkeep Cost Reduction (IUCR)"; IUCR makes industry responsible for the supply of assets along with the maintenance of spares and is incentivised to reduce the cost of spares. Whereas in the third one which is recognised as Incentivised Reliability Improvement (IRI), industry is contracted for the supply of assets along with the maintenance of spares and is incentivised to reduce costs by improving the reliability of assets [5].

The aim of this chapter is to introduce two solutions, first based on current available technologies and second a futuristic solution for optimising time and cost across the supply chain for delivering spare part contract. To achieve this in Sect. 28.2 a comprehensive explanation for the supply chain for the spare part has been given. Section 28.2.1 describes the first suggested method for optimising time and cost across the supply chain based on current capacities of industries. Section 28.2 is introducing a futuristic method which can have dramatic impact on "Administrative Delay Time" (ADT), "Logistic Delay Time" (LDT) and "Procurement Delay Time" (PDT). Section 28.3 discusses and concludes the chapter.

## 28.2 The Supply Chain for the Spare Part Contracts

As a general definition, supply chain refers to the flow of raw materials and information from suppliers to end users as a product, as well as the flow of information from the end users to the suppliers [6]. However, supply chain can vary in different contexts. Figures 28.1 and 28.2 illustrate a high level supply chain for delivering a product and a spare part contract as a service.

A general supply chain with high level segments to deliver a product has been extracted from [6] and has been illustrated in Fig. 28.1.

A general supply chain with high level segments to deliver spare part contracts in military context has been extracted from [5] and illustrated in Fig. 28.2.

It can be spotted from Figs. 28.1 and 28.2 that the supply chain for delivering a service specifically delivering a spare part contract has different segments in comparison to the ordinary supply chain for delivering a product.

Studying the supply chain and its segments could be one of the initial endeavours to find ways to reduce the overall cost and to optimise the absolute time for delivering a service or a product regardless of the supply chain type.

Efforts to start identifying relationships between different facilities and segments in a supply chain for an organisation were initiated by [7]. Since then, efforts and endeavours expand on the dependencies between the different segments of the supply chain have been carried on. Studying the required cost and time in different segments and sections of the supply chain can lead to a path to optimise the supply chain overall cost and the lead time.

To clarify the above paragraph, lead time and cost have inverse relation across the supply chain. Often seeking for less delivery time, impose higher cost to service provider. On the other hand, enduring longer delivery time (i.e. to a certain level which does not cause penalising the service provider) slightly reduce costs. Due to above relation between the overall cost and the lead time, there are enormously different answers with different cost and time for delivering a specific service by a certain service provider to the customer. The mentioned logic between cost and time in the supply chain has been illustrated in Fig. 28.3.

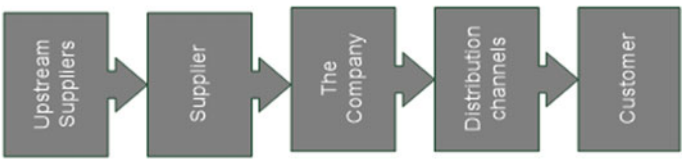


**Fig. 28.1** General supply chain for delivering a product


**Fig. 28.2** General supply chain for spare part delivery

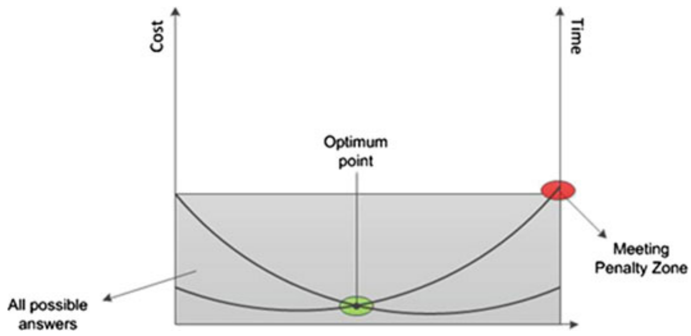


**Fig. 28.3** Total cost and time behaviour across the whole supply chain

Selecting a point among all possible answers and then comparing it with all other points can be an approach to help decision makers to take an appropriate decision regarding situations. In addition, among all possible answers there is an optimum point which offers the best service delivery time with minimum cost.

The first solution which is a trading-off tool for helping decision makers has been introduced according to current technologies and considering current capacities. However, second solution which is more a futuristic solution that does not seem costly logical for numerous types of industries nowadays. This futuristic solution is introducing a novel solution to improve spare parts contracts through the exploitation of Additive Manufacturing. Additive manufacturing as a new introduced technology in industries can be used regarding saving time and improving service delivery time.

The first solution provides an optimum delivery time of spares without affecting the cost of delivery of services or it can be used inversely as a framework for finding the optimum point of overall cost of service delivery in a defined time pattern by the customer. The second solution provides an improved delivery time of spares given the elimination of the "Administrative Delay Time" and a dramatic reduction of the "Logistics Delay Time".

### *28.2.1 Methodology*

The presented framework in the Fig. 28.4 has been developed using "the Soft System Methodology" (SSM) and through primary research based on unstructured interviews with experts of servitisation, service delivery firms and "Ministry of Defence" (MoD). All achieved information was validated by experts in DS2 firms.

One workshop has been held as an initial stage for gathering information and identifying the main perspectives of supply chain from customer and service provider point of view. The main conclusion of the workshop was that lead time and

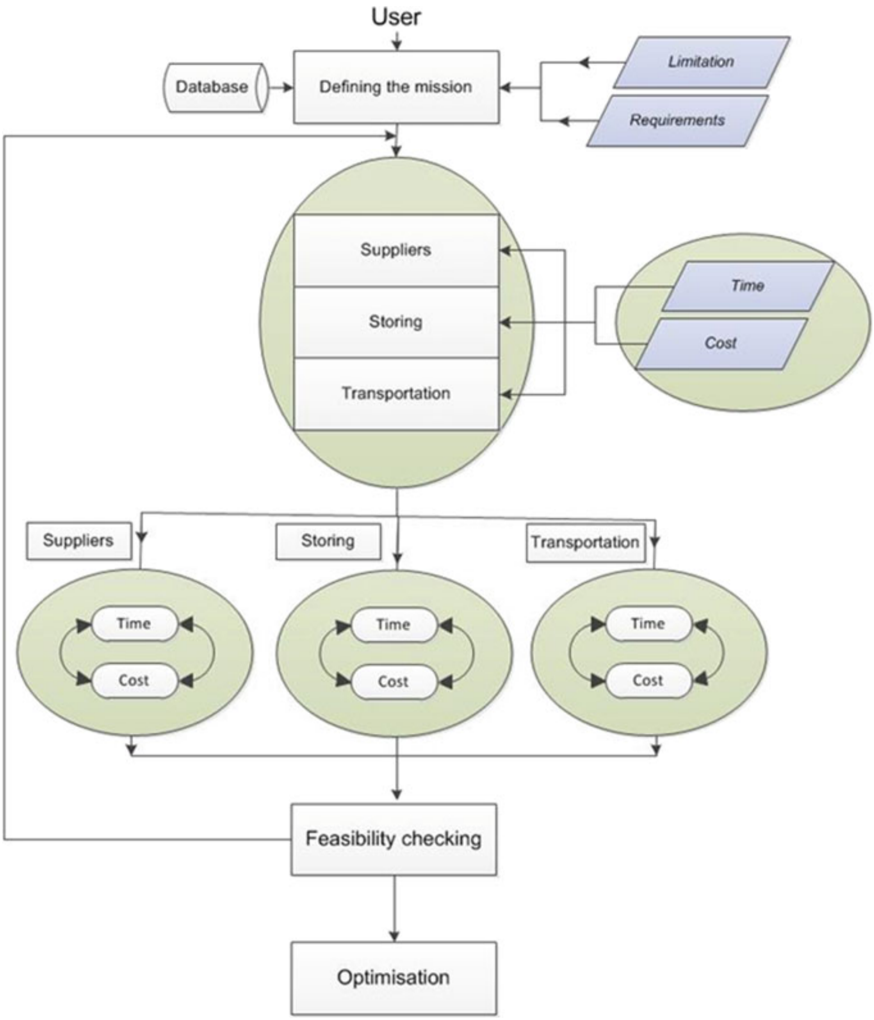


**Fig. 28.4** A trade-off analysis framework for delivering spare part contracts

cost as two dependent main drivers across the supply chain and various segments of it, should be the back bone of presented trade-off framework.

Almost 8 interviews have been carried out with individual experts in the servitisation, service delivery and modelling experts. The general outcome of the mentioned interviews was identifying main decision making processes across the supply chain and also categorising the constraints for the optimisation process.

Two interviews have been conducted with contract bidding managers to form the penalising system and its activation process.

The general outcome is the presented framework in Fig. 28.4.

### 28.2.2 Lead Time and Overall Cost Trade-Off Analysis

As it was discussed in Sect. 28.2, the supply chain of spare part contracts as a part of servitisation process has its own characteristics and segments.

Ability to calculate the effects of modifications in the lead time and the cost in different segments of the supply chain could assist manager for decision making in different aspects e.g. prediction of the consequences of investments in different part of the supply chain, prediction of using or improving alternative methods for manufacturing, transportation and etc. This gap can be filled by presenting a framework which does the trade-off analysis to modify the effect of changes in the lead time and overall cost.

The presented framework in the Fig. 28.4 is a time-cost trade-off analysis which is looking at the supply chain from the service provider's perspective.

According to the defined spare part contracts by MOD which has been fully covered in Sect. 28.1 and also considering the generic spare part contract, which is covered in this section; there are three key decisions which must be taken by service providers. Firstly involved selecting the supplier, second involves selecting a location to store and the method and lastly the transportation method. Each of above mentioned key decisions are based on required delivery time and involved cost of each alternative as the two main drivers.

The introduced framework consists of three main stages. The initial stage is extracting data from the database or generating information about suppliers' details, available transportation systems and their details and storing options and their details as inputs from the user and then by defining the mission the first stage will be finished. User's inputs and identified or extracted information from the database are the main drivers for decision making process. The decision making process is according to trade-off theory. The trade-off occurs among all related costs and time as limitations, requirements and human resources. At this stage trading off occurs in parallel for selecting a supplier, transportation method and storing method.

To clarify the decision making part; time and cost are the two main drivers for trading off and observing the effect of different suppliers, various transportation methods and storing options on the overall cost and absolute lead time of supply chain. In the second stage, a trade-off between two main drivers for various suppliers from different perspective e.g. geographical locations of suppliers and ware houses, required facilities for transportation and storing, the item's cost and required time to deliver a specific item from specific supplier and all other requirements and limitation which were defined in the first stage would be considered.

The third stage in the framework is the feasibility checking step by considering all different cases with different suppliers, storing method and transportation method and effect of each scenario on the overall cost and the total lead time.

There are some constraints for each project which have been defined in the first stage (Defining mission section). The constraints are (1) the maximum delivery time without meeting any penalty for late delivery; (2) defining a method to calculate the penalty system. (3) considering any geographical point for storing. (4) Defining the maximum spendable budget for each section (providing items from suppliers, transportation methods and storing methods) and also defining the maximum spendable budget for the whole project.

All these constraints play a vital role in the optimisation stage. Each of mentioned constraints eliminates a number of possible answers. At the end the optimum point of overall cost within the defined time pattern would be obtained. However, if there is no possible answer in the defined time pattern then the penalising system is going to be activated.

Penalising system is punishing method (or sometimes encouraging method) which often is suggested from customer to service provider. If service provider missed the agreed deadline with a customer then the service provider is going to be under the penalising system. Defining the penalising method often happens in the bid stage of the contract and usually there is an exponential relationship between time and cost while the penalty system is activated.

This section outlined the trade–off framework to help decision makers to find out about different scenarios across the supply chain for delivering spare parts contracts and finding the optimum point for the supply chain. The following section outlines a novel solution to improve spare parts contracts through the exploitation of Additive Manufacturing.

### *28.2.3 Additive Manufacturing Solution*

The following section aims to present the application of "Additive Manufacturing" (AM) within "Defence Support Services" (DS2) and a framework for assessing the impact and supporting the implementation of the AM technology within the Defence sector. The framework is made up of 8 mutually exclusive phases which collectively provide the decision makers an exhaustive analysis of the impact of the AM implementation. As follows, DS2, AM and the framework are presented and explained.

DS2 providers have the capability to deliver the availability of their own or third party systems/equipment to their customer, in this case the Royal Navy. The Royal Navy operates in mission and safety critical environments through the deployment of its platforms. These platforms such as the Type 45 destroyer, Type 23 frigate and the Astute Class submarine are featured with an extended number of sophisticated and complex engineering systems which allows the platforms to deliver its capability and survive in critical and potentially hostile environments. For the Royal Navy the availability of its complex engineering systems is a critical factor which is measured through uptime over total time. The most influential elements of the availability ratio are given by the "Administrative Delay Time" (ADT) and the "Logistic Delay Time" (LDT).

Through the exploitation of AM, DS2 can explore new solutions to support the Royal Navy's complex engineering system. The main idea is to improve the efficiency of the overall service system by eliminating the ADT and LDT through the delocalisation of AM in the front-end of a DS2 system. This solution allows manufacturing the required component next to the point of use. "Additive Manufacturing" (AM) is a disruptive technology which benefits from design freedom, short manufacturing lead times, low buy-to-fly ratios, complexity for free and requires limited space for operating. It can be used for both, printing new components and repair broken ones (if combined with machining and 3D scanner). Moreover the technology has the potential to reduce or eliminate sub-assemblies, access to new geometries and improve the performance of components. AM from a production perspective is lean, it benefits from "pull" and "just-in-time" moreover the technology can process random geometries without any impact on setups. Given the limited space requirements by AM, mini-factories can be developed within containers and deployed in forward bases in order to reduce the distance to the point of use. This allows eliminates the planning of components required (forecasted) and production of only what is actually required in the battlefield. Mini-factories can be developed for in-platform deployment which will eliminate the LDT. Furthermore "Wire + Arc Additive Manufacturing" (WAAM) is an AM technology which is not present in international standards but is considered the most promising technology for industrial applications. Firstly it is a wire based technology which implies no health and safety issues compared with powder solutions, easy material feed, medium cost of wire, nearly 100% material efficiency. Featured with high deposition rates (kg/h), low BTF ratios (2), low cost of investment (max £200 k), high energy efficiency (90%), good accuracy (1–2 mm), low product cost and manufacturing lead times (hrs), the deposition occurs out of the chamber with unlimited size constraints and lower space required. This technology also benefits from good design freedom and topological optimisation opportunity, good mechanical properties and microstructure and no porosity. WAAM is intended for large, fully dense functional components.

To assess the costs and benefits of AM in support services for the Royal Navy and evaluate the impact, a conceptual framework has been developed by [8] and is presented in Fig. 28.5—**Conceptual Framework**. The framework is the result of a collaborative research carried out with the "Ministry of Defence" (MoD), and a leading British Support Service provider of the Royal Navy.

The framework has been developed using "Soft System Methodology" (SSM) and through primary research based on unstructured interviews with experts of DS2 firms and "Ministry of Defence" (MoD). The methodology is outlined in Fig. 28.6 and is made of four phases. Phase 1 consists in the definition of the situation and the problem faced, in this case the emergence of a promising technology, AM and the opportunity to improve the efficiency of the support service system. Phase 2 investigates the current practices, where a system approach has been adopted in order to define a standard of a DS2, its elements, links, triggering events and key performance indicators. Phase 3 involves the development of the framework which is based on the analysis of available AM technologies (from a system perspective) and current DS2 practices. Finally, Phase 4 involves the

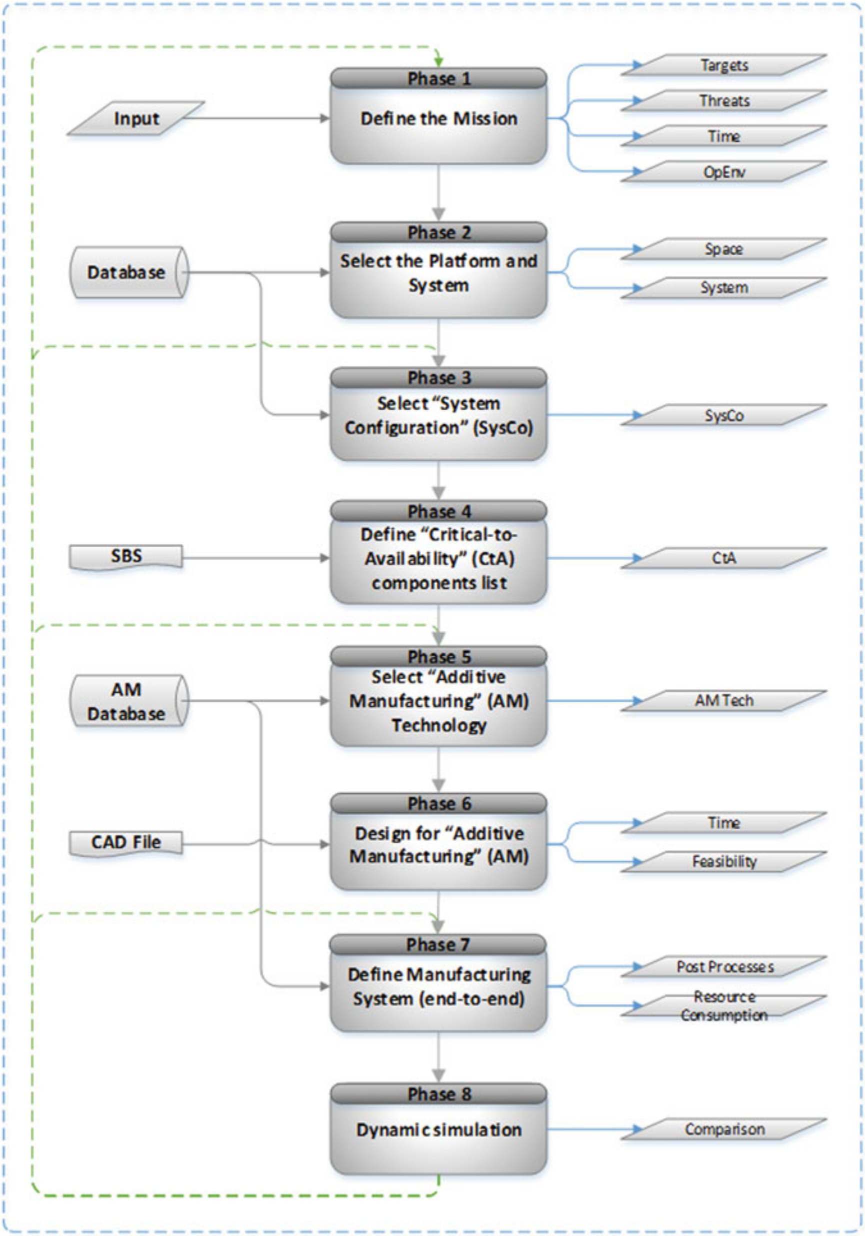


**Fig. 28.5** Conceptual Framework

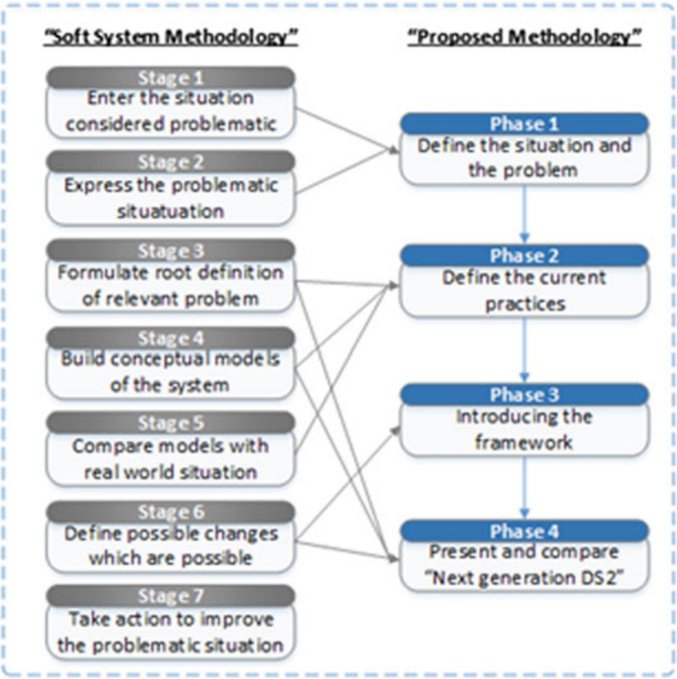


**Fig. 28.6** Methodology

comparison of the current practices with the next generation ones based on AM deployed in the front-end of the support service system.

Expertise has been elicited and captured during two workshops which lasted several hours. The results of the workshop have been used to feed a conceptual modelling phase in which the framework has been defined in order to make an exhaustive and holistic assessment of AM applications in DS2. Finally, the result of the conceptual modelling phase outlined in Fig. 28.5—Conceptual Framework have been verified and validated through expert judgement.

The framework has been implemented into a "Decision Support System" (DSS) tool which aims to support critical managerial and technical decision making on the acquisition and implementation of Additive Manufacturing in the Defence Support Service sector. The DSS aims to simulate probabilistically different system configurations available and outline "Key Performance Indicators" (KPI) such as time, cost and benefits. The simulations outlined the following aspects have been observed: (1) AM can be deployed in a defensive platform, a support vessel or a forward base. The impact of AM in DS2 is substantial; firstly it improves dramatically the efficiency of the support to availability of CES, given the elimination of the "Administrative Delay Time" (ADT), "Logistic Delay Time" (LDT) and "Procurement Delay Time" (PDT). Secondly it reduces the supply chain complexity given the supplies of only wire and powders. Thirdly it reduces the time and the cost of the support service with a related reduction of total cost of ownership. Finally, providing flexible manufacturing capability to a defensive platform in a battlefield featured with disrupted supply chain may improve its ability to recover capability and improve its survivability and lethality.

This section has presented a conceptual framework to assess the technical benefits of Additive Manufacturing technology's deployment in the context of support services. Moreover strategic benefits on deployed AM capability have been outlined providing a comprehensive view on the impact of the technology. Results show that AM, if exploited for support service sector, may provide cost, time and availability advantages to both the end user and the service provider.

## 28.3 Discussion and Conclusion

Due to enthusiasm and demands toward servitisation in different industries such as aerospace and defence, delivering services is becoming more common than before [1]. According to literature, regarding current capacities, extracting and obtaining the maximum output is vital to survive in the current market as well as having futuristic view [9]. This chapter aims to introduce two novel solutions to maximise outputs within the spare parts contract, according to current capacities of industries and a next generation solution.

The first introduced solution is a decision making framework based on current capacities of industries for delivering spare part contracts as part of the servitisation process. Available literature in decision making process for the supply chain in different sector has been studied and the outcome of the literature review was finding a gap in this section. The gap led to develop a framework which has been introduced in Sect. 28.1 of this chapter. The main aim of developed framework is to help decision makers for gaining the optimum decision for delivering services in the spare part contract. Also the framework has an added value for trading off among the enrolled criteria.

The framework is based on trade-off theory consisting of two main role variables (cost and time) across the supply chain. There are three decision making processes involved in the framework, a feasibility checking method and an optimising method at the end. The first decision making is for selecting a supplier, second one is for selecting a transportation method and the third one is for selecting a storing method. Outputs' feasibility of all those three decision making process would be checked in the next stage of framework. All feasible outcomes shall be used in the optimisation stage of framework toward finding the optimum point of overall cost of service delivery in a defined time pattern by the customer. Novelties of the framework consist of 1—Three parallel pairwise decisions making in the service supply chain from providers' point of view and. 2—Considering penalising system and the exponential relation between time and cost while most considered penalising system are linear [10] when the penalty system is activated. The next generation solution, based on the application of AM in the front-end of a DS2 system provides opportunities for dramatic improvement in terms of efficiency and effectiveness of the system. This is mainly due to the reduction of the LDT. Having AM capability in the front-end of the system provides firstly an improved availability of CES and secondly reduces the cost related with delivering the support service. In order to support the acquisition programs on AM and structure the implementation within DS2, an exhaustive framework has been developed. The framework supports critical decision making by providing estimates on costs and benefits of the various AM delocalisation options. The framework has been implemented into a "Decision Support System" (DSS) software tool which allows users to retrieve immediate estimates on AM implementations and compare instantly the KPIs of current and next generation practices. Results shows that the next generation practices based on AM provide improved service and costs savings to both the support service provider and the owner of the platform.

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