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Product-Service Systems across Life Cycle

Towards an Integrated Decision Making Framework for Aero Engine MRO Contract Management in the Productisation Context

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Abstract

One of the most critical elements in the 'productisation' of service adopted by today's aero-engine Maintenance Repair and Overhaul (MRO) companies is the match between customer demands and the operational capabilities of the MRO shop. Currently, the service contract is offered based upon experience and intuition rather than on scientific approach. This paper presents an integrated decision making framework to design contracts that considers demand and operational parameters. In addition to literature survey, the approach adopted in building the framework is a case study research, which obtains data from semi-structured interviews, observations and the company archives. Two main perspectives, dynamic operational parameters and shop floor operational parameters, were identified as essential and pertinent to the design and management of the service contract in the productisation context. The framework will incorporate both perspectives to support productisation.

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Keywords: IPSS; Service Provider; non-OEM MRO; Contract; Productisation

1. Introduction

The aviation industry has evolved its business model based on the servitisation concept. Aero-engine Manufacturers (OEMs) have offered the new business model using utilization-based selling, i.e., availability based contracts. This allowed OEMs to expand their core business as manufacturers to MRO (Maintenance-Repair-Overhaul) service. OEM MRO now supports all the operational requirements of the assets (i.e. aero-engine). This situation results in shifting risks and uncertainties to the service provider from customers [1]. Many approaches have been conducted to minimize risks and uncertainties, such as enhanced sensor technology application regarding health monitoring and prognosis in real time [2]. This data will then be used to take the advantages from condition based maintenance. Through this philosophy, OEMs have secured their position in the aftermarket MRO service provision. An OEM MRO service provider has a higher state of readiness, as they are supported by larger resources, has greater capacity and capability than a non-OEM MRO service provider, and has the OEM's authorisation [3].

Traditionally, *non-OEM MRO service providers* were offering repair-only services. This trend, however, forced them to become more competitive in retaining their market, despite their handicaps compared with OEM MRO. They now deploy a similar business model to their competitors, i.e., combining their service offer with products. This business model is called productisation. In addition, non-OEM MRO service providers are obliged to offer lower cost solutions with higher flexibility (e.g., shorter maintenance lead time) than their competitors.

To do so, non-OEM MRO service providers need better contracting design capability. Traditionally, their contract design method didn't have to be sophisticated beyond experience and intuition. However, since now a new contract requires to be more precise and robust in estimated cost, TAT, and other key performance indicators, the contract design

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method must be scientifically sound and reflect the reality of the shop floor as well.

This study aims to build a decision making assessment method to assist non-OEM MRO to prepare an optimal contract offer. This method will help the decision makers of non-OEM MRO service providers to assess the risk for each new contract scenario. To accomplish this, the following research questions were defined: How to apply the productisation concept to non-OEM MRO service providers? What are the technical parameters that influence productisation deployment?

This paper is structured as follows. Section 2 describes the background of this research, both from the industrial needs and theoretical knowledge, based on the literature research conducted. Section 3 describes the collected data and its analysis. Section 4 illustrates the framework development. The paper concludes, by presenting the contributions of this study and the limitations of this research which are translated in the future research agenda.

2. Literature Review

2.1. Servitisation of Products

The servitisation of products is applied by the industrial services or manufacturers which produce goods. In 1989, Vandermehwe and Rada discussed a definition of servitisation [4]. Then, Morelli stated that servitisation was a new approach to enhance the fulfilment of the user's needs [5]. Baines concluded that PSS was 'the innovation of an organisation's capabilities and processes to create better mutual value through a shift from selling a product to selling PSS' [6].

Servitisation of products has been applied in several industries such as ABB [7], Rolls-Royce [8] and Thales Training and Simulation [7]. Through the integrated product service offerings, these high capital assets providers demonstrate its uniqueness, longevity and how it enhances the value of the product offers by providing customers with required deliverables outcomes [8,9].

In the aerospace industry, many high value capital goods manufacturers have deployed the servitisation concept to their offers. Rolls-Royce is offering "power by the hour" contracts to their customers. Thales has offered training simulation for pilots. These are examples of enhancing their position as service solution provider to customers, rather than a traditional goods producer.

2.2. Productisation of Services

The service industry delivers intangible activities that can be contrasted with tangible products. To enrich services, the service industry employs a productisation business model. The productisation concept will clarify and enhance understanding of the service offering and make it repeatable [10].

Although the term "productisation" appeared in 1986 [11] as the creation of products, in 2005 productisation was defined as, turning services into products by bundling services and packaging them into a fixed price under a certain brand name [12]. Then, Valminen and Tovailanen stated that "productisation refers to an activity, where the service offering is made through a systematization of its components" [13].

The term productisation was then used in the context of service providers, particularly of education service providers, KIBS (knowledge intensive business services) and IT industry. Productisation manages all the supporting needs in providing an offer to the customer. The supporting needs can be a system, or an additional product which functions as a platform to deliver the services. One of the best examples is the BT telephony service. BT bundled its service with products such as a telephone set or internet modem.

Following this understanding, an aero-engine non-OEM MRO service provider is able to consider productisation business models with a particular type of aero-engine. They can offer productisation services for mature engine type, e.g., CFM 56-3. Because of its maturity, it is often cheaper to buy a second-hand CFM 56-3 than its maintenance cost. In contrast, the maintenance cost for a more modern engine type is significantly expensive than the price of a second hand CFM56-3. The non-OEM MRO service provider has responded to this situation by bundling the MRO service with the engine as a spare engine offer to the customers. This allows them to offer an MRO contract with a higher availability level.

The productisation business model needs a different approach in providing its contract. First, the customer requirement should be assessed based on their needs, e.g., flight planning operations. Then, the service provider assesses their own capacity and capability to fulfil the requirements. The assessment result can reveal the total resources needed, i.e., the number of aero-engine that have to be provided based on both the demanded requirement and the capability and capacity of the MRO service provider, which includes all policies from the strategic level to operational level management.

However, this does not imply that a service provider such as MRO service providers and leasing companies are able to provide similar offer. MRO service contracts that allow fluctuating demand have resulted in a need to develop flexible capability and capacity of the shop floor.

2.3. Productisation in Aero-Engine Business Model

Based on literatures (article, journal paper, internet article magazine) there found several productisation levels, which then, related to the aero-engine MRO industry as examples (Fig. 1).

The traditional business model of an MRO service provider is similar to an automobile garage (Fig. 2a). An airline will enquire a certain maintenance work scope to the MRO service provider. Then the MRO service provider will manage all necessary requirements (manpower, tools, materials, and assets) to deliver pure MRO service provider to the customer. This situation relates to the productisation defined as an activity, where the service offering is made through its components' systematisation [13]

The second productisation definition presents the service offer to be more product like which is more tangible and easier to replicate [10]. The service provider offers MRO service package that are quantified and measured by total man hours per maintenance package. This situation makes maintenance service package offer is easier to replicate and understand. It became more tangible as a package offers.

The third of the productisation is to offer a total solution. The total solution integrates both the service and the products to fulfil the customers' requirements [14]. In this stage, the MRO service provider adding tangible product (i.e., aero-engine) to their service offer. The output of this model makes the service provider as the total solution provider.

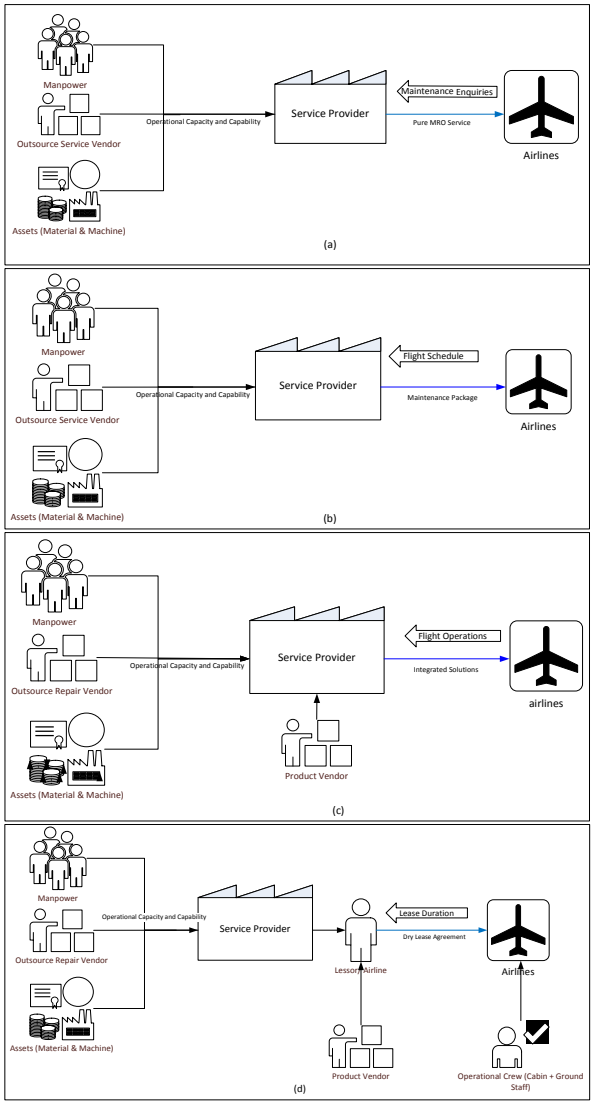

Fig. 1 Productisation Business Model in Aero Engine MRO Industry

3. Case Study

In this research, the case study used combinations of data collection, interviews, archives and observations. A case company has been chosen, as it employs the productisation business model. In addition, this company allows unlimited data access to the researcher. This case company has initiated the adoption of the productisation business model, by offering a bundled service with aero-engines to an airline. This case company purchased the used aero-engines and offers them to the airline customer bundled in the MRO service contract. These situations made this company an ideal case to study.

Observation and semi-structured interviews have been conducted in order to identify and analyses the concrete cases of issues that exist for the MRO service provider. The observation was held during the annual workshop between the case company and key customer A. The workshop, attended by 42 people, consisted of top and middle managers. Each manager representing a section of the aircraft MRO operations (i.e., engine maintenance, line maintenance, component maintenance, cabin maintenance, airframe maintenance, and painting maintenance). The workshop reached several important decisions that need to be carried out in order to fulfil the airline's operational planning for the following year. To add detail to the decisions reached during the workshop, the study selected senior and middle managers of the case company to become interviewees. These interviewees consist of 12 people who have about 113 years of combined experience in the same industry. The duration of each interview is between 60-120 minutes, covering several topics: airline demand characteristics, trend of the airline's demand, current contractual agreement deployed and the decision making processes in contract offers. The findings obtained from the interviews were then used to enhance understanding-related parameters, to develop the decision-making assessment method. This method acts as a foundation to provide methodology in the contract design decision-making. It will be applicable to the operational level.

During one interviews, a senior manager in the case company mentioned that airline demand had shifted into the operation capable aircraft rate. An operation capable aircraft has to meet the On-Time Performance (OTP) level. OTP is the capability level of an aircraft to fulfil the scheduled commercial mission. Therefore, the MRO service provider has set the best optimum strategy to fulfil the operational requirements from the airlines.

In addition, passenger demand is set to increase in the future. To cope with the situation, airlines tend to have higher frequency operations. Higher frequency operations can be best supported by narrow-body aircraft. This situation forces airlines to operate more narrow-body than the wide body aircraft. The shift of the airline fleet composition has forced the MRO service provider to adjust its service planning strategy. Currently, MRO service providers tend to increase their resource level only in response to this long-term trend, including new facilities and the spare parts inventory level.

Another issue is the temporary aircraft operations planning. Airlines often change their operations for various reasons and circumstances (i.e., cabin crew pairing, maintenance route,

climate situations). The MRO service provider needs to respond to this adjustment. In the maintenance operations itself, the MRO service providers have to decide several critical parameters, to optimise shop floor operations. Limited capability and capacity have made these parameters more critical than before. They usually decide to conduct the maintenance contract based on intuitions, rather than scientific approaches.

As there were no 'fact-based' supporting decision parameters, the shop floor divisions often stretched their TAT target, which could reduce the competitiveness advantage for the MRO service provider. This situation occurs because there is no adequate linkage between the contract preparation team and the shop floor. The main gaps found were the simultaneous lack of methodology in making decisions, which assess the maintenance demand and the shop floor availability.

4. Framework Development

This study conducted a grounded-theory analysis to identity data that was important, and to investigate themes arising from the interview. These findings were then concluded into several categories. The study analysed the interview transcripts to evaluate the categories and the usefulness of the information. Then, the study grouped the common data to assist the analysis.

The final analysis of the observation and interview then revealed the most important parameter, which became the foundation of the contract agreement, namely the On-Time-Performance level. This refers to the total number of operations required to fulfil the planned mission. Within the scope of the airlines, it translates as required Time-On-Wing (TOW). Figure 2 illustrates several parameters that could affect the total TOW of an aero-engine.

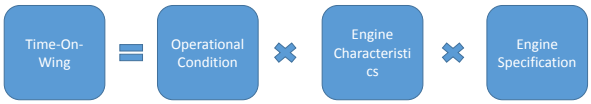

Fig. 2 Time-On-Wing Equation

The TOW is influenced by several factors, both from the aero-engine lifecycle reliability and the shop floor operations reliability. The greater reliability of the aero engine will increase the potential TOW produced by the asset. Once the aero-engine is overhauled or serviced, the shop floor operations reliability will also increase the TOW, by reducing the ground-time.

The operational condition can consist of several parameters, such as the total load factor of an aircraft, the tail wind, pilot behaviour, etc. In this study, the operational condition will be limited to the geographical and operational temperature parameter. However, these parameters will not only affect the reliability but also the lifecycle of the aero engine.

Engine characteristics will comprise the historical maintenance data such as the flight cycle since new (FCSN), flight hours since new (FHSN), flight cycle since last shop visit (FCSV), and flight hours since last shop visit (FHSV). These parameters will represent the aero-engine's age.

Engine specifications will also influence the reliability of the engine. These include the thrust level, de-rate factor of aero-engine, available EGT (Exhaust Gas Temperature) margin.

The outcomes from the preliminary research through observation, interview and literature research became the foundation of the proposed enhanced assessment method, developed in several iterations with inputs from both theory and practice. In contrast with the existing contract design system, the proposed method takes the airline parameters operations as drivers. In addition, the framework integrates an illustration on how contract design methodology can be collaborated with shop floor operations assessment.

The first phase of the assessment method will assess the future maintenance demand, by incorporating its operational parameters (i.e. flight hours, flight cycle, historical maintenance data, severity, geographical and environmental situation). The second phase will assess the shop floor operational capability and capacity (i.e. manpower, material, methods, and tools).

4.1. Asset Operational Parameters

The maintenance event of the aero-engine can be divided into the scheduled maintenance and unscheduled maintenance. The scheduled maintenance can be divided, based on its work scope, Life Limited Parts (LLP) replacement or the performance restoration. The LLP replacement, is based on the cycle and the performance restoration, measured by the available EGT margin. The unscheduled maintenance events usually result from incidents such as foreign object damage (FOD) or the components failure. The component failures prediction can be enhanced from the severity factors [15].

The operational aero-engine parameters in the operations have been related to the geographical situation and its severity factors [16,17]. The geographical situation of the aero-engine will affect the dynamic operational behaviour of the aircraft. For example, the climate situation in the desert will result in the lower level of available EGT margin and the total cycle of the aero-engines in the contract durations.

To enhance the maintenance event characteristics of aero-engines, there are parameters that have to be incorporated in the forecast prediction. Based on the literature, those external parameters have to be taken into account during maintenance event schedule prediction.

The customer operations requirements will also influence the number of aero-engines. The reliability of the engine, combined with the customer operations requirement, can be used to optimise the number of aero engines required.

To enhance the accuracy, it is necessary to assess the life cycle of each aero engine in the fleet during the duration of the partnership between the customer and the MRO service provider. The life cycle simulation will then assess the economic feasibility of the aero-engine to combine with the maintenance package as a cost [18].

4.2. Shop Floor Capability and Capacity Parameters

Once it becomes clear that the obtained reliability can support the customer's operational requirements, the MRO service provider needs also to assess their own capacity and capability at the shop floor in conducting maintenance. The service provider can only provide contracted service level only when they have adequate capacity and capabilities, which can be evaluated with a modelling approach [19].

The total maintenance duration of an aero-engine in the shop floor depends on several parameters, such as availability of manpower, tools, materials, machines and their method of working. The shorter maintenance duration will increase the TOW operations. It means that the shop floor maintenance reliability can affect the engine availability as the output deliverable. Therefore, there is a need to evaluate whether or not the shop floor operations match the need of the maintenance event in the future.

4.3. Enhanced Integrated Conceptual Framework Model

This study developed a conceptual model framework that serves as the methodological foundation of contract preparation for non-OEM MRO service providers (Fig. 3). The methodology assesses both the maintenance demand event and the shop floor capability and availability simultaneously. In the proposed conceptual framework, the productisation business model which offers the availability contract has to assess not only the customer's domain but also their capacity's domain. The interface between these domains is the maintenance demand planning which will be translated into a resource planning.

The customer's domain requirements consist of parameters which have direct impact on the availability of the aero-engines. They consist of the flight plans, current engine condition and the maintenance information. Flight plan will represent the total flight hours and flight cycle needed by the airlines in the duration of the contract. Engine condition represent the specification of the optimum operations range based on manufacturer's recommendation. In addition, the maintenance information will help the next maintenance work scope's prediction.

The calculation between the flight operations requirement and the situation of the engine will result in the maintenance demand planning. Through this assessment, an MRO service provider could arrange and allocate the necessary resources to support the operations. The shop floor capacity and capability operations depend on the available resources, manpower, material, tools and machines.

The model is supported by a process framework and a set of tools that enable it to provide further detail at operational level, which is conducted in practice. The decision-making process in the contract design is influenced by the airline's operational requirements and MRO service provider resources.

The use of resource assessment in decision-making, includes the shop floor availability and capability readiness, while it provides data for the decision makers to make informed decisions. Our conceptual framework model, illustrates the fact that there is a need to communicate between organisations (strategic and operational level) so that the service contract offers in the higher level can be deployed in the shop floor level.

The use of the framework depicted in Figure 3, facilitates the shift from decision making, based on experience and intuition to a more scientific method.

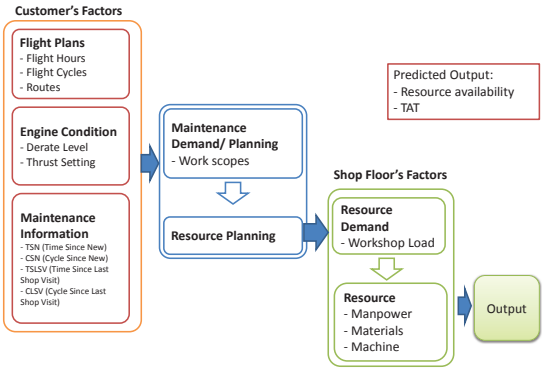

Fig. 3 Conceptual Framework of Contract Design

5. Discussions

To maintain their competitiveness, service providers have integrated products with service, as a solution offer to their customers. However, the current service design process cannot support the new business model with the productisation concept. In literature, there are no adequate PSS design methods for a service provider looking to this direction. Current PSS design decision frameworks in the literature often assess the customer's perspective only or the PSS providers only. The combination of the both perspectives is a novel contribution of this work.

In the productisation business model, the service provider has an opportunity to enhance their competitiveness by delivering the right service offers to the customers. The service provider will be able to assess the customers' needs and to match their operational capability to fulfil the requirements.

The framework for decision-making during contract preparation will take the operational factors, as well as the resource availability into consideration. The operational factors are needed to predict the maintenance demand of the assets. These factors are then used to calculate the time and date of the maintenance required for each engine. The known maintenance events can be used to plan the resources and the availability. The simultaneous output will be ascertained from the methodology, as to which resources must be added or reduced, to fulfil the maintenance demand.

The operational factors mentioned, are the parameters to predict the maintenance demand. The known parameters such as the specification of the aero-engine and the maintenance history data of the aero-engine, are used to predict the scheduled maintenance. This unscheduled maintenance also needs to be assessed to address the risk and uncertainty. This unscheduled maintenance may result in difficulties for the shop floor operations in the firefighting mode. To address this

matter, the severity factors based on the flight operations have been taken into account. The severity factors and the aero-engine specification are closely related and used to predict the severity of each aero-engine.

Situation predictions for individual engine maintenance events will be assessed more easily in the prediction, but in this case, the contract design will cover a fleet of aero-engines for a certain period. Therefore, the shop floor capability and capacity must be ready and able to accommodate the maintenance needs with an adequate level of resources and on time.

The assessment of this methodology will deliver the total resources that are needed and/or that are available to accommodate the airline operations. The resources numbers consist of the total aero-engine needed, capabilities and capacity of the shop floor facilities and labour force needed for operations.

6. Conclusions

The conceptual model framework in this paper, was built based on both existing literature and case studies. The model presents a decision-making methodology which accommodates the operational level strategy and is intended to support customer requirements at the same time. The framework can provide a basis for many tools to be employed by the practitioners in gaining competitive advantage, by providing customer demand and taking into consideration the impact of availability and capacity of quantities on the shop floor.

The framework proposes to address several challenges faced by non-OEM MRO that apply productisation of service. First, by assessing the productisation of service strategy in the real industry, it provides a foundation that is lacking in the existing productisation of service application literature. For the industry, by aligning the maintenance operational availability and capability, the framework balances the operational level and strategic level direction of the service provider.

Recommendations for further work are to develop a business model simulation to represent the real industry scenarios. These scenarios planning analysis can then be used by the industry in assessing the suitable productisation business model based on their requirements.

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