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Inventory optimization for a customer airline in a Performance Based Contract

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ABSTRACT

The supply of spare parts has a crucial role in the aviation sector, mainly due to the high costs of spare parts and to the strict availability requirements. In a stand-alone scenario, an airline owns the spare parts and manages the maintenance tasks by itself. A new trend consists of not owning the spare parts and delegate the maintenance tasks to an external company, taking advantage of a specific Performance Based Contract (PBC). The PBCs aim to reduce the ownership cost for the customer airline, while ensuring a target system performance. Spare parts become a variable cost for the customer airline and a business income for the maintenance supplier, which is commonly another airline.

This paper proposes an innovative model, i.e. the PBC-METRIC, which supports the customer airline manager to minimize the spare parts supply cost, in compliance with the airline availability requirements and with respect to the PBC. In detail, the PBC-METRIC models a multi-echelon, multi-item, single-indenture, multi-transportation network, by an innovative two-steps algorithm, defining the PBC specifications as modelling variables and parameters. A case study on a European airline, with the role of customer in a PBC, illustrates the outcome of the model.

1. Introduction

In transportation industry, defence sector, oil drilling, telecommunication and other industries, a reliable spare parts supply is a key element to provide service continuity. High inventory levels generally minimize the critical consequences of stock-outs, even in case of remote suppliers and long procurement times. However, a high inventory level generates significant stock cost. Determining the optimum inventory level for spare parts becomes a crucial strategic target for complex systems. In these cases, it is necessary to adopt the so-called system approach, which evolves the classic item approach, as prescribed by Sherbrooke's METRIC (Sherbrooke, 1968). In details, the item approach aims to define an economic order quantity and period for each item, without considering possible interactions among them in terms of global availability. On the contrary, the system approach permits to define an availability-cost function with inventory costs and required service levels for the entire system. Although it may indirectly offer measures for the supply system performance (e.g. fill rate and number of backorders), it proposes measures in accordance with the manager or the decision-maker perspective. For example the system approach answers questions such as “What are the costs to ensure a 95% global availability? How much money do we need to spend to have an enhancement in our global availability? What does the optimal system cost-effectiveness curve look like?”

The system approach uses availability and investment targets as inputs to the decision-making process. It presents an availability-cost curve, in which the manager can easily choose the point that meets the availability constraints within budget limitations. Note that to obtain these outputs it is necessary to solve a series of item approach problems by efficient solving techniques that consider multiple conflicting goals. One of more of these features generally characterize a complex system for which it is generally fruitful to adopt a system approach:

- Commonality: different systems may have some parts in common. The manager can decide to stock these parts separately for each system or in a shared inventory;
- Service differentiation: systems may require differentiated availability levels, according the criticality levels of the sites;
- Multi-transportation modes: it is possible to transport the items in different ways from central to local warehouses;
- Multi-echelon structure: a service supply chain generally consists of central and local warehouse, where central warehouses replenish the local ones;

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- Lateral transhipment: this aspect concerns the possibility that a local warehouse provides a spare part to another local warehouse that is out of stock. In this case it is necessary a jointly optimization of the warehouses.

In particular, the aeronautical industry is one of the sectors where many of these features characterize the systems.

The International Air Transport Association (IATA)'s Maintenance Cost Task Force (IATA, 2011) shows that maintenance cost takes up about 13% of the total operating cost. While aircraft spare parts with very high price are generally not in stock (e.g. engines), and low-cost items are available in every location in a short time, stock levels for medium-range Line Replaceable Units (LRUs) require careful sizing.

As a competitive advantage to decrease these inventory costs, some airlines aims to outsource the ownership of spare parts stocks, settling contracts which regulates the performance in terms of spare parts availability. The company that manages the spare parts inventory and maintenance is the maintenance supplier. This latter is commonly another airline that benefits of risk compensation, considering the high unlikelihood of simultaneous breakdowns. Spare parts become a variable cost for the customer airline and a business income for the maintenance supplier. More formally, in these cases, the supplier proposes a Performance Based Contract (PBC) and the airline that decides to submit it, becomes the customer airline. Besides the access to the supplier inventory, generally these contracts allow the customer to stock a reduced subset of spare parts in its warehouse, paying an additional tax to the supplier. Therefore, determining the items to stock and their stock levels acquires a fundamental role in all the supply activities.

More generally, a Performance Based Contract is a results-oriented contract focusing on the outputs, quality or outcomes that may tie at least a portion of a contractor's payment, contract extensions, or contract renewals to the achievement of specific, measurable performance standards and requirements. These contracts may include both monetary and non-monetary incentives and disincentives.

What emerged from the literature review is a lack of any specific Performance Based Contract model and related solving procedure. To this extent, the contribution of the paper is to present a functional description, a mathematical modelling and an innovative two steps algorithm, based on METRIC, to fill this gap for a typical Performance Based Contract. The main role of the paper in this research field is to provide a first view on a two-party interaction, looking at the customer airline side. While the main literature on METRIC considers a multi-echelon structure of a single organization, where the optimization of the whole system depends on the complete knowledge of all the parameters, the model developed in this study supports managers to outsource the spare parts management processes, in order to reach a target availability while minimizing costs, under contractual constraints.

In summary, the structure of the paper is as follows. Firstly, the literature review in Section 2 shows the potentiality of the system approach, focusing on the METRIC research. It also highlights the importance of Performance Based Contract in the aviation industry. Section 3 describes the features of the Performance Based Contract model that will be the core of this research. Section 4 develops an innovative two steps algorithm, based on METRIC. Section 5 presents the case study, relative to a European airline that submit a Performance Based Contract as the customer airline. Lastly, Section 6 summarizes the outcomes of the study and the possibility for further research.

2. Literature review

From the fundamental work of Sherbrooke (Sherbrooke, 1968), the research on spare parts management considers a system-oriented inventory problem, developing many evolutions of the original Multi-Echelon Technique for Recoverable Item Control (METRIC) model. According to a general point of view, the METRIC objective is to allocate the spare parts, ensuring the parts fill rate and the minimum holding or backorder cost, subject to an availability constraint. A significant amount of METRIC-like models provide extensions to the original one, introducing multi-item, i.e. the MOD-METRIC (Muckstad, 1973), multi-indenture, i.e. the VARI-METRIC (Sherbrooke, 1986), multi-echelon network (Graves, 1985) and different demand models (Lee and Moinzadeh, 1987). Hillestad and Carrillo (1980) developed the Dyna-METRIC to take into account the systems under time-dependant operational demands and logistic decision, typical of a wartime scenarios. Some authors integrate the level of repair analysis (Alfredsson, 1997; Basten et al., 2011; Driessen et al., 2014), the capacity constraints of the maintenance centres (Selçuk, 2013; Sleptchenko et al., 2002; Zijm and Avşar, 2003) even in terms of certified skills of the Maintenance Repair and Overhaul provider (Costantino et al., 2013).

The wide application in several industries confirms the importance of these models. For example, Rustenburg et al. (2000) develop a METRIC-like model for the Royal Netherlands Navy. Sun et al. (2009) propose a METRIC model for the weapon equipment industry. Sun et al. (2010), Sun and Zuo (2013), (2010) for the civil airline context. Costantino et al. (2010) for the military aviation, Alvarez and van der Heijden (2014) for a defence systems environment. Moreover, Basten and van Houtum (2014) account several software solution based on METRIC-like models, e.g. OPUS10, MCA Solutions, Xelus, Inventri, VMetric.

Considering the demonstrated potentiality of METRIC, this study strives to customize the standard METRIC formulation, in order to develop a model that better fits the need of a customer airline in a Performance Based Contract. In the aircraft spare parts supply, as well as in other industry, the Performance Based Contract constitutes a new service model in supply management (Jin et al., 2013), with potential critical reshaping of the supply network both for commercial airlines and for defence industry (Zhang et al., 2014).

In the commercial aviation context, Performance Based Contract arises from the possibility of sharing inventory (or part of it) among different airlines, following the principles of risk pooling: the variability of demand reduces if multiple demands across different locations aggregate. Firstly, Kilpi et al. (2009) examined the possible cooperation among different airlines. They underlined how at that time there was no evidence of formal coordination in real life, but just courtesy behaviours among airlines selling spare parts each other to face emergencies. In the commercial context, the raise of Performance Based Contract started after the collaboration pool set by the International Airlines Technical Pool association (IATP). IATP started by the pooled resources for Maintenance Repair and Overhaul of KLM, Sabena and Swissair, and now offers 11 pooled recovery kit all around the world (Harbison, 2014).

This paper focuses on a specific Performance Based Contract for spare parts supply, where the supplier owns the spare parts and the customer pays for the maintenance services. This Performance Based Contract reflects many contracts available among producers (e.g. Airbus, Boeing Company, Rolls Royce) or airlines (e.g. Air China Technic, Air France Industries, KLM Engineering & Maintenance, British Airways Engineering, Delta TechOps, Lufthansa Technik). In all these contracts, these companies provide Maintenance Repair and Overhaul services to potential customers. Therefore, the model in this paper shall be capable of managing the Performance Based Contract specifications. For this purpose, it is necessary to translate common Performance Based Contract measures such as fill rate and turnaround time into measures suitable for the METRIC model (i.e. pipeline, backorders, and availability). About fill rate and shipping time, generally set as Performance Based Contract specifications, Verrijdt et al. (1998) introduce the turnaround time variability in a