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A two-step method for forecasting spare parts demand using information on component repairs

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ABSTRACT

Forecasting spare parts demand is notoriously difficult, as demand is typically intermittent and lumpy. Specialized methods such as that by Croston are available, but these are not based on the repair operations that cause the intermittency and lumpiness of demand. In this paper, we do propose a method that, in addition to the demand for spare parts, considers the type of component repaired. This two-step forecasting method separately updates the average number of parts needed per repair and the number of repairs for each type of component. The method is tested in an empirical, comparative study for a service provider in the aviation industry. Our results show that the two-step method is one of the most accurate methods, and that it performs considerably better than Croston's method. Moreover, contrary to other methods, the two-step method can use information on planned maintenance and repair operations to reduce forecasts errors by up to 20%. We derive further analytical and simulation results that help explain the empirical findings.

1. Introduction

This paper is, in the first place, motivated by the problem of forecasting spare parts demand at Fokker Services, a company that maintains and repairs aircraft components. Fokker Services is one of the five businesses of Fokker Technologies, which develops and produces advanced structures and electrical systems for the aviation and aerospace industry, and supplies integrated services and products to aircraft owners and operators. At Fokker Services, expensive spare parts have to be stocked in order to quickly carry out repairs. Therefore, forecasting demand is an important issue at Fokker, and more generally in the spare part industry. Boone et al. (2008) reports from a Delphi study with senior service part managers that demand forecasting is the key challenge in service parts management. Better forecasting techniques might reduce safety stocks and thus might reduce costs without reducing service levels.

Fokker Services has detailed data over a 10 year period that links spare parts demand to the type of component repaired, and the number of spare parts used per component repair. This raises the interesting question of whether this link can be used to more accurately forecast demand. Standard forecasting methods, such as exponential smoothing and moving average, as well as specialized methods such as that by Croston (1972), only consider demand for spare parts and not the underlying repair process. However, that repair process does, in part, cause the intermittent and lumpy demand patterns that complicate spare parts forecasting. In this paper, we propose a new, so-called two-step forecasting method that does take the additional repair information into account. In the first step we forecast, for each type of component, the number of repairs per time unit of that component and the number of spare parts (of the type under consideration) needed per repair of that component. In the second step, these forecasts are combined to forecast total demand for a spare part. The rationale behind this method is that the ability to recognize what causes a change in the demand for spare parts, contrary to existing methods, should lead to better demand forecasts. For instance, a drop in demand for a spare part at Fokker Services may result either from aircrafts being taken out of use, or from finding new ways (based on improved technology) of repairing rather than replacing parts of a failed component. In this example, the former case will imply a reduction in the number of repairs for certain components, while the latter will affect the number of parts needed per repair.

We use the data set of Fokker Services to compare the two-step methods with several traditional methods, such as exponential smoothing, moving average, Croston's method, and a recently proposed method by Teunter et al. (2011). Based on the mean square error (MSE), mean absolute deviation (MAD), and mean error (ME), we conclude that the two-step method is one of the best performing methods, and that it considerably outperforms the well-known Croston method. Furthermore, by taking information on the planning of maintenance and repair operations into account, the

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forecasts errors of the two-step method can be reduced by up to 20%. Other methods cannot benefit from this information as they do not link demand at the part level to specific repair operations.

The remainder of this paper is organized as follows. Section 2 gives an overview of the relevant literature. Section 3 describes the data and in Section 4 the various forecasting methods are introduced. Section 5 summarizes the results of our case study and in Section 6 a simulation study gives insights into the differences between the new two-step method and exponential smoothing. Finally, we give some concluding remarks and directions for future research in Section 7.

2. Relevant literature

We restrict ourselves in this review to forecasting demand, we refer to Guide and Srivastava (1997) and Kennedy et al. (2002) for more general overviews on spare parts management. In fact, we concentrate on the forecasting contributions that are most relevant for our study and refer to Boylan and Syntetos (2010) for a comprehensive review on forecasting spare parts demand.

Forecasting demand has been an important issue for many years. Traditional methods include moving average and exponential smoothing, see e.g. Axsäter (2006). Exponential smoothing in particular has shown itself to be a very robust forecast method that is able to adapt quickly to changes in the demand process, and it is widely used in practice. However, Croston (1972) has shown that both exponential smoothing and moving average do not perform well for intermittent demand, i.e. when there are many periods with zero demand. He proposes to update the demand size and the demand interval separately using exponential smoothing. Updates are only carried out in periods with positive demands.

Syntetos and Boylan (2001) show that Croston's method is biased and suggest an adjustment to overcome this issue in a follow-up paper (Syntetos and Boylan, 2005). Other variants of Croston's method are suggested in the literature as well. In a comparative study, Teunter and Sani (2009) show that the variants of Syntetos (2001) and Syntetos and Boylan (2005) are the most promising ones. Other studies compare variants of Croston's method with traditional methods; see e.g. Willemain et al. (1994), Ghobbar and Friend (2003), and Eaves and Kingman (2004). These studies show that most variants outperform traditional methods on average, but not for all possible situations.

Teunter et al. (2011) show that the Croston approach is not suited to deal with obsolescence issues. They propose to update the demand probability instead of the demand interval. The advantage is that the demand probability can be updated every period, whereas the demand interval can only be updated in a period with a positive demand.

Bootstrapping offers a non-parametric alternative for forecasting spare parts demand. Similar to the above discussed methods, forecasts are based purely on the demand history. However, rather then specifying a certain updating structure for the forecast and associated forecasting error, sample statistics are used to estimate the demand distribution. Bootstrapping methods range from very simple (Efron, 1979; Porras and Dekker, 2008) to more complex (Willemain et al., 2004).

Some authors have also considered to use types of information other than historic demand, such as installed base information (Song and Zipkin, 1996; Jalil et al., 2011), reliability information (Petrovic and Petrovic, 1992) and expert judgment (Syntetos et al., 2009). Wang and Syntetos (2011) discuss a maintenance based model for forecasting spare part demand which uses information on the demand generation process. However, they do not take into account that spare parts might be used in the repair for various types of components. To the best of our knowledge, no methods have previously been proposed that make use of information on the type of component whose repair generated the demand for a spare part, as we do in this study.

3. Data description

The data set contains information on over 100,000 repairs at Fokker Services during the period from 01-01-2000 till 28-02-2010. For each repair the date of issue, the type of component that is repaired, and the spare parts used are recorded. Some repairs do not require any spare parts, others require many spare parts of various types. In total 3329 different types of components are repaired, and 17,012 different types of spare parts are used during these repairs. Forecasting at Fokker Services is carried out on a monthly basis and this is typical in the service industry. Therefore, monthly aggregates are created.

The first seven years, i.e., the period from 01-01-2000 till 31-12-2006, represents the initialization period. This is about two-third of the total period, similar as in Teunter and Duncan (2009). During this period the forecasting methods are initialized; see Section 4.8. Note that spare parts that are not demanded during the initialization period are left out of consideration.

Spare parts are categorized based on the number of months with positive demand during the initialization period. The three categories are very-slow moving (1–5 months with positive demand), slow moving (6–20 months), and fast moving (21–84 months). We could have created further categories by considering the lumpiness of the demand size as well (as in Syntetos et al., 2005), but preliminary tests showed demand 'speed' to have the most significant effect on the comparative results that we study. The choice of boundaries between the three categories is somewhat arbitrary, but ensures in line with traditional ABC analysis that the slowest moving category contains the largest number of parts and the fastest moving category contains the smallest number of parts. Furthermore, different boundaries that we considered produced similar results to those that we will present. Table 1 gives an overview of the three categories.

4. Forecasting methods

In this section, all considered forecasting methods are described. Table 2 gives an overview of these methods and their

Table 1
An overview of the three spare part categories. All statistics are calculated using the aggregate monthly data during the initialization period.

	Number of part types	Avg. monthly demand	Avg. number of demands per year
Very-slow moving	6015	0.0514	0.301
Slow moving	2865	0.340	1.541
Fast moving	1696	3.134	5.735

Table 2
The forecasting methods used and their abbreviations.

Abbreviation	Method
ZF	Zero forecast
NF	Naive forecast
MA	Moving average forecast
ES	Exponential smoothing forecast
CR	Croston's forecasting method
SBA	Syntetos–Boylan approximation
TSB	Teunter–Syntetos–Babai forecasting method
2S	Two-step forecast