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Spare part demand forecasting for consumer goods using installed base information

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ABSTRACT

When stopping production, the manufacturer has to decide on the lot size in the final production run to cover spare part demand during the end-of-life phase. This decision can be supported by forecasting how much demand is expected in the future. Forecasts can be obtained from the installed base of the product, that is, the number of products still in use. This type of information is relatively easily available in case of B2B maintenance contracts, but it is more complicated in B2C spare parts supply management. Consumer decisions on whether or not to repair a malfunctioning product depend on the specific product and spare part. Further, consumers may differ in their decisions, for example, for products with fast innovations and changing social trends. Consumer behavior can be accounted for by using appropriate types of installed base, for example, lifetime installed base for essential spare parts of expensive products with long lifecycle, and warranty installed base for products with short lifecycle. This paper proposes a set of installed base concepts with associated simple empirical forecasting methodologies that can be applied in practice for B2C spare parts supply management during the end-of-life phase of consumer products. The methodology is illustrated by case studies for eighteen spare parts of six products from a consumer electronics company. The research hypotheses on which installed base type performs best under which conditions are supported in the majority of cases, and forecasts obtained from installed base are substantially better than simple black box forecasts. Incorporating past sales via installed base therefore supports final production decisions to cover future consumer demand for spare parts.

1. Introduction

For owners and users, it is frustrating if a product or system can no longer be used because a small component failed and spare parts are not available. The timely availability of spare parts is therefore an important issue for users, especially for ageing products. Providing spare parts, however, is a challenge for Original Equipment Manufacturers (OEMs), as users can be spread over the world and demand is typically intermittent (Boylan & Syntetos, 2009). In many cases, demand is high for some parts and very small for other parts, resulting in surplus stocks. Forecasting the location and size of demand per spare part is therefore an important aspect in spare parts management. It plays a major role in determining the final production run that should guarantee parts availability for the remaining service life (see e.g. Van der Heijden & Iskandar, 2013). It is also important to determine where and how much parts should be in stock, especially if the demand is decreasing.

Much research has been devoted to forecasting spare parts demand. Boylan and Syntetos (2009) give a recent overview of methods available so far. They propose a three phase approach, with pre-processing, processing and post-processing. In the pre-processing phase, one classifies the spare parts and selects the forecasting method, which is then applied per class in the second phase. Finally, the obtained forecasts are adjusted in the post-processing phase. The forecasting methods considered by Boylan and Syntetos (2009) are all based on demand data only, without taking any other information into account, similar to forecasting sales of new products. However, forecasting spare parts demand differs from forecasting demand for new products because spare parts are only needed to repair products which are still in use. Hence the location and number of products in use, also called the *Installed Base* (IB), is of primary interest as generator of spare parts demand. Several authors, including Jalil, Zuidwijk, and

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Fleischmann (2011) and Dekker, Pince, Zuidwijk, and Jalil (2013), have therefore proposed to use IB as the causal variable in forecasting spare parts demand. This kind of approach requires that companies keep track of their IB. That is possible in B2B cases, such as planes (Fokker Services), high-end computers (IBM), or advanced chip making machines (ASML), as users of these expensive systems have service contracts with manufacturers to guarantee timely parts supply. IB forecasting then consists of establishing the demand per product and forecasting the future development of IB. This two-step forecasting procedure does require some work in practice because products may have been adapted for customers and demand may also be influenced by local conditions (Jalil et al., 2011).

Although the aforementioned companies all apply IB forecasting, less advanced companies tend to rely only on parts demand data. In an empirical review of seven industrial companies, Wagner and Lindemann (2008) state: "However, most of the case study companies, regardless of their size, have only a 'cloudy view' of their current installed base." In the consumer business area, the contacts between users and manufacturers are even less established and manufacturers usually have little information on their installed base. They are likely to know the number of sales per region, but they generally do not have data on how many products are still in use and when they will be phased out, which is the crucial information for predicting future demand of spare parts. In this paper, we therefore introduce new part classifications and related installed base concepts that can be used in the pre-processing phase of forecasting consumer demand for spare parts and that require a relatively limited amount of management information. The proposed installed base concepts are lifetime IB, warranty IB, economic IB, and mixed IB. Use of lifetime IB assumes that all products stay in the market according to their expected lifetime, which holds mostly for expensive products. Warranty IB assumes that spare parts demand is limited to products for which a warranty still applies. Economic IB assumes that products are discarded when repairs are no longer economic, which is relevant especially for products that evolve quickly, for example, due to technological innovations. Finally, mixed IB is a refinement of economic IB that applies when consumers show heterogeneity in their evaluation of the costs and benefits of repair. These IB concepts will be elaborated and they will be empirically validated through a comparison with standard forecasting for a sample of real cases drawn from a major consumer products manufacturer.

The remainder of this paper is structured as follows. Section 2 discusses some background literature, presents the employed concepts of installed base, and formulates the main research hypotheses. The methodology is described in Section 3, and it is illustrated in detail for a specific spare part in Section 4. Section 5 presents the results for a set of eighteen spare parts related to six products. Section 6 concludes and summarizes operational implications.

2. Installed base

2.1. Background literature

The main topic of this paper is spare part demand forecasting for consumer products over their end-of-life phase, using the concept of installed base (IB). We review some background literature on IB forecasting and on the end-of-life production decision, where it should be noted that the term 'installed base' has not always been used in the past for describing this concept.

One of the first authors considering life-cycles of products and their related spare parts demand is Yamashina (1989). Assuming given product failure rates and given development of the installed base, he gives formulas for the demand for spare parts. Cohen, Kamesam, Kleindorfer, Lee, and Tekerian (1990) mention IB as a possible way of updating forecasts, without going into detail. Brockhoff and Rao (1993) use the IB concept to forecast new product adoption, and Auramo and Ala-Risku (2005) focus on how to obtain IB information in service logistics. Wagner and Lindemann (2008) perform an empirical study on spare parts management within seven engineering companies. They consider the IB concept as part of advanced forecasting and observe that companies have problems in keeping track of their IB and hence have to resort to forecasting based on parts demand only. Hong, Koo, Lee, and Ahn (2008) consider forecasting of discontinued products and base their forecasts on the number of product sales (without mentioning the term IB), the discard rate of the product, the failure rate of the service part, and the replacement probability of the failed part. They illustrate their approach with data from an automobile factory. Jin and Liao (2009) use IB within a simulation context for inventory control to satisfy maintenance demand for spare parts and assume that the IB is known. Thereafter, Jalil et al. (2011) describe further experience with IBM and highlight the value of the IB concept. Dekker et al. (2013) review the use of this concept and its application at several companies. Minner (2011) combines reliability models with inventory control to arrive at better forecasts than those obtained by time series analysis, and he evaluates his approach by simulation data. Jin and Tian (2012) use the IB concept in optimizing inventory control policies in case of increasing demand. They illustrate their method by simulations and they do not consider forecasting. Bacchetti and Saccani (2012) provide an extensive overview of spare parts demand forecasting. They investigate the currently still existing gap between research and practice in spare parts management, and they also identify issues in obtaining the IB, using information from Wagner and Lindemann (2008). Finally, Chou, Hsu, and Lin (2015) use the concept of IB to forecast final orders of automobile parts. Their first finding is that production costs are higher during end-of-life (EOL) than during the mature phase because of loss of economies of scale and of economies of scope. Second, they find that the optimal warranty period during EOL depends on product failure rates.

All the aforementioned contributions to the IB literature assume that the IB information is readily available, or they mention that obtaining this information is an open issue. In practice, this assumption is reasonable only for advanced companies in a business-to-business environment. Further, most papers focus on modeling and determining optimal inventory control policies instead of doing empirical analysis with real data. Our contribution lies in proposing IB concepts that can be applied in practice for B2C supply management of spare parts by means of IB-based empirical demand forecasts during the end-of-life phase of consumer products. We therefore mention some contributions on the question of the final production run or final order size, which is also called the end-of-life decision, and we compare them to our research setting. Teunter and Fortuin (1998) optimize the final order size by minimizing costs for machines with known finite lifetime. They do not evaluate actual forecast accuracy, and their method requires information on production costs, holding costs, and penalty costs that are unavailable in our case. Tibben-Lemke and Amato (2001) predict demand for replacement parts from known failure ratios. Our products have unknown failure ratios, and demand also depends on heterogeneous consumer preferences. Kim and Park (2008) stress the importance of demand forecasting for the EOL phase to decide on final order sizes. Teunter, Syntetos, and Babai (2011) base their forecasts of sporadic demand on probabilities and potential benefits are illustrated by simulation, not with real data. Islam and Meade (2000) analyze factors inducing replacement rather than repair, including socio-economic factors and improved technology. Pourakbar, Frenk, and Dekker (2012), Pourakbar, Van der Laan, and Dekker (2014) consider final order