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Empirically-driven hierarchical classification of stock keeping units

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ABSTRACT

This paper proposes a hierarchical multi-criteria classification method developed for inventory management purposes and applied in a case study of the spare parts business of a household appliance manufacturer. The classification method is built on the basis of SIX dimensions, resulting in 12 different classes of spare parts, for which differentiated forecasting and inventory policies are proposed and tested. The results of our simulation study demonstrate the reduction of the total logistics costs by about 20% whilst still achieving the specified target service level for each class. Even more importantly, the proposed approach is simple enough to be understood and applied by company managers, thus increasing the probability of its adoption (in the same or similar fashion) in other real world settings.

1. Introduction

The after sales spare parts business contributes considerably to the total revenue and profitability of modern manufacturing organisations (Gallagher et al., 2005; Cohen and Agrawal, 2006). Research on spare parts demand and inventory management has developed rapidly in recent years with new results implemented into software solutions because of the importance in practice. However, practical applications lag considerably behind the relevant theoretical propositions in this area. In particular, spare parts management in the context of durable consumer products is an area that has been traditionally overlooked (Cohen et al., 1997). As a result, the management techniques adopted are often not differentiated from the ones used for finished products or components used in production (Boylan and Syntetos, 2008), and several companies suffer the implications of poor demand forecasts and inappropriate inventory policies (Boone et al., 2008).

An important issue is that of categorising the Stock Keeping Units (SKUs) to facilitate decision-making, i.e. select appropriate forecasting and stock control methods and set appropriate targets. However, the majority of research papers in this area focus on the development of new methods with little attention towards implementation related requirements and empirical implications (Dekker and Bayindir, 2004; Bacchetti and Saccani, 2012). Such a gap exemplifies the need for case study research.

In this paper, we are concerned with the design and empirical validation of a hierarchical multi-criteria classification method aimed to facilitate inventory management and enable the differentiation of planning choices according to spare parts specificities. The classification method is developed through a case study of a household appliance manufacturer. Our contribution is two-fold. First we discuss the construction of the classification framework and the process of spare parts management re-engineering, allowing insights to be gained into pertinent managerial factors. Second, we evaluate the implications of such a framework in the case study organisation enabling the linkage between process performance and process development.

The remainder of our paper is structured as follows. In the next Section 2 the guidelines offered in the literature on spare parts classification and their applications to industrial case studies are reviewed. Section 3 describes the case study organisation and Section 4 outlines the development of the multi-criteria classification method. The utility of the proposed solution is empirically assessed in Section 5 while in Section 6 we point out the implications of this work for the Operations Management theory and practice. Conclusions are offered in Section 7 along with the natural next steps of research in this area.

2. Research background

2.1. Literature on classification of SKUs

Several factors render demand and inventory management for spare parts a very complex matter; a few among them are (a) the high number of parts managed (Cohen and Agrawal, 2006), (b) the presence of lumpy demand patterns (Boylan and Syntetos, 2010), (c) the high responsiveness required by customers due to downtime costs (Murthy et al., 2004), and (d) the risk of stock obsolescence (Cohen and Agrawal, 2006). In such a context, the categorisation of SKUs helps to determine service requirements

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for different classes and facilitates the allocation of the most appropriate forecasting method and stock control policy in each category.

Bacchetti and Saccani (2012) reviewed the academic literature concerned with classification related issues for spare parts management, pointing out the different classification criteria proposed. The most commonly used ones were found to be the part unit cost/value, the part criticality, the demand volume or value, the supply characteristics (such as the replenishment lead time, supplier availability and risk of non-supply), and the demand variability. Less cited criteria are the part life cycle phase and the part specificity. We further elaborate on that study, analysing for the most common groups of criteria, the options suggested in the literature and the proposed threshold (cut-off) values, as summarised in Table 1.

Contrasting the works reviewed in Table 1 with real world practices some gaps can be pointed out. First of all, very little attention has been paid to identifying the specific cases in which the adoption of one criterion may be advised instead of another. This is a very important issue and one that is seriously under-exposed in the academic literature. Moreover, as Table 1 suggests, very few papers discuss the operationalisation of classification methods in practice, either in terms of the specification of the classes, or the number of classes, the determination of the cut-off values etc. In addition, although the problem of spare parts categorisation is multi-dimensional in nature, the shortness of data available and the companies′ priority on easy-to-use and implementable systems imply that complex mathematical approaches may be rarely considered suitable in practice (Jouni et al., 2011; Botter and Fortuin, 2000). As such, rules-of-thumb are often used (Huiskonen, 2001; Nenes et al., 2010) and single- or two-criteria classifications are employed (Bacchetti and Saccani, 2012). Despite this, only a few papers offer managerial guidelines about spare parts classification through industrial case studies. In summary, the shortage of papers that consider (i) operationalisation; (ii) contextual implementation advice; and (iii) managerial insights reflects the gap between theory and practice in the area of spare parts management and the scope for considerable contributions in this area.

2.2. Industrial case studies

Six case studies reported in the literature have been selected, that address situations similar to the one described later in this paper. Indeed, they deal with spare parts management in manufacturing companies servicing directly, or through a third party network, an installed base of durable products geographically dispersed (Nagarur et al., 1994; Kalchschmidt et al., 2003; Persson and Saccani, 2009; Syntetos et al., 2009b), or wholesalers or distributors selling a large amount of items with irregular or lumpy demand to a large customer base (Nenes et al., 2010; Syntetos et al., 2010). On the other hand, cases reporting spare parts and MROs (maintenance, repair and operations) materials management methodologies in a single company for its own production systems are not considered, since they refer to technical systems and do not match the scope of this study. The cases are summarised in Table 2. In summary, the reported cases suggest that simple but carefully designed and well-informed solutions for spare parts may offer substantial benefits in terms of cost reduction, service level improvement and increased transparency of the inventory management methods. This further demonstrates the previously discussed discrepancy between theory and practice of spare parts management according to which the latter lags considerably behind the former.

3. The case study organisation

The case study presented in this paper refers to a large white goods manufacturer, headquartered in Italy. It sells and delivers household appliances and spare parts all over the world. It provides after-sales services, warranty management, spare parts distribution and repair services through several external repair centres. The

Table 1
Overview of the classification criteria in the literature and the suggested cut-off values.

Part/unit cost	Several papers consider this criterion jointly with others: threshold values are defined in conjunction with other criteria (Ernst and Cohen, 1990; Partovi and Anandarajan, 2002; Chen et al., 2006; Ramanathan, 2006; Zhou and Fan, 2007; Ng, 2007). It is also common that two or three levels/classes are proposed (Petrovic and Petrovic, 1992; Nagarur et al., 1994; Huiskonen, 2001; Braglia et al., 2004; Cavalieri et al., 2008), which are determined qualitatively (e.g. high/low) with unspecified cut-off values. Porras and Dekker (2008) propose a five-level classification based on cut-off values related to a case study organisation
Part Criticality	The criterion is qualitative in nature. Most papers suggest the definition of two or three criticality levels based on a direct judgmental evaluation (Flores and Whybark, 1988; Petrovic and Petrovic, 1992; Huiskonen, 2001; Persson and Saccani, 2009), or the evaluation of sub criteria (Cavalieri et al., 2008). In some cases an Analytical Hierarchy Process (AHP) methodology is proposed (Gajpal et al., 1994; Braglia et al., 2004), clustering (Duchessi et al., 1988; Ernst and Cohen, 1990) or weighted average methods (Chen et al., 2006; Ramanathan, 2006; Chu et al., 2008)
Demand volume/value	Generally, ABC classifications are used on the cumulative annual demand volume or value, based on ad-hoc Pareto-based threshold values (Flores and Whybark, 1988; Syntetos et al., 2009b), or on clustering techniques (Duchessi et al., 1988), or on qualitative characterisations (e.g. high/low—Huiskonen, 2001; Persson and Saccani, 2009). Several papers consider this criterion jointly with others: threshold values are defined in conjunction with the other criteria (Ernst and Cohen, 1990; Partovi and Anandarajan, 2002; Chen et al., 2006; Ramanathan, 2006; Zhou and Fan, 2007; Ng, 2007). Some papers address demand frequency (Gelders and Van Looy, 1978; Porras and Dekker, 2008) with ad-hoc cut-off values, or take a reliability perspective (Petrovic and Petrovic, 1992; Braglia et al., 2004)
Supply characteristics/ uncertainty	The evaluation is based on the supply lead time (Gajpal et al., 1994) or supplier distance (Nagarur et al., 1994) with unspecified or ad-hoc cut-off values. In Braglia et al. (2004) several sub-criteria are considered through an AHP methodology. Eaves and Kingsman (2004), considering lead time variability, state: "*the choice of boundaries between each of the categories is essentially a management decision*" (p. 432). Persson and Saccani (2009) report the part availability on the market from competitors as a classification criterion
Demand characteristics	Lead-time demand variability is addressed by Williams (1984) and Eaves and Kingsman (2004). Syntetos et al. (2005) categorise demand according to the squared coefficient of variation of the demand sizes and the average demand interval. Both the parameters and cut-off values are obtained analytically and are further empirically validated on 3000 real-intermittent demand data series (SKUs) suggesting their robustness in a variety of contexts. Boylan et al. 2008 showed through a case study analysis with a software manufacturer the insensitivity of the average inter-demand interval cut-off value in the range 1.18–1.86
Life cycle phase	The criterion is suggested by Yamashina (1989). In the case described by Persson and Saccani (2009) four phases are considered, with case-based cut-off values depending on the number of years from which the equipment is being manufactured, or by the time passed since the production ended