

A case study-based analysis of spare parts management in the engineering industry

S.M. Wagner^{a*} and E. Lindemann^b

^aDepartment of Management, Technology, and Economics, Swiss Federal Institute of Technology Zurich, Switzerland;

^bKuehne Foundation Endowed Chair of Logistics Management, WHU – Otto Beisheim School of Management, Germany

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Eroding margins for primary products have redirected many firms' attention to the highly profitable spare parts business. These firms push for increased sales and more efficient spare parts supply chains. However, previous research in spare parts supply chain management has principally been limited to planning and operational aspects such as the determination of spare parts inventory levels and re-order policies. Taking the sellers' perspective in the supply chain, the primary objective of the case study research presented in this article is to better understand the problems that engineering companies encounter and approaches that they adopt in their spare parts supply chains. The initial proposition, that engineering companies need to, and are eager to, adopt supply chain management practices in their spare parts businesses in order to capture revenue and profit potential, is supported. Among the key areas for improvement are the formulation of spare parts strategies, a better understanding of the installed base, and top management support for the spare parts business.

Keywords: spare parts management; supply chains; strategy; engineering industry; case studies

1. Introduction

The spare parts business is often called 'the most profitable function of a corporation' (Suomala *et al.* 2002, p. 65). Recent studies revealed that after-sales services and the selling of spare parts contribute roughly 25% to the revenues and 40 to 50% to the profits of manufacturing and engineering-driven firms (Dennis and Kambil 2003, Cohen 2005). The economic importance of the spare parts business is also underlined by the fact that the aftermarket for spare parts and services accounts for 8% of the annual gross domestic product of the USA (Cohen 2005).

Despite the importance of the spare parts business on the firm and macro-economic levels, the previous literature on spare parts management is quite limited. It has focused primarily on the planning and operational aspects (e.g. the determination of optimum spare parts inventory levels) and has neglected the strategic and organisational problems manufacturing companies have to solve in order to manage their spare parts business effectively. The increasing importance of spare parts sales for the performance of companies calls for improved and innovative concepts and strategies in this area. Therefore, the goals of this article are:

- (1) To assess the problems that engineering companies are facing in their spare parts business.

- (2) To shed light on recent developments in this area.
- (3) To make recommendations for successful spare parts management in the engineering industry.

Taken as a whole, this study constitutes a valuable source for urgently needed future research on strategic spare parts management.

The rest of the article is structured as follows: Section 2 reviews and categorises the literature on supply chain management aspects for spare parts. Section 3 describes the case study-based approach underlying this research in detail. Section 4 highlights the importance of supply chain management for spare parts for the engineering companies investigated in the course of this research and discusses how companies actually deal with the challenges they are facing. Managerial implications are drawn in Section 5.

2. Literature review

2.1 Primary products vs. spare parts

Successful supply chain management (SCM) requires decisions on three levels and with respect to three time-horizons: (1) strategy or design, (2) planning, and (3) operations (Chopra and Meindl 2007). While the issues of the supply chain strategy/design level have a long-term focus on the strategic decision-making

*Corresponding author. Email: stwagner@ethz.ch

processes, the planning and operations categories take a tactical or operational view with a shorter time horizon. Hence the supply chain strategy/design level encompasses decision problems such as make-or-buy, site selection, and long-term capacity planning. Planning and operational level decisions are related to demand forecasting or determination of inventory levels. Successful SCM requires firms to set up and optimise their SCM activities and processes on both, the design/strategy and planning/operations levels. For this reason, research needs to provide concepts and optimisation approaches in both areas.

SCM for primary products (e.g. machines in engineering companies or cars in the automobile industry) has received substantial research attention. In this context, researchers have examined a broad range of issues related to decisions on both supply chain levels. Table 1 depicts several issues and

related references that deal with SCM for primary products.

With respect to SCM for spare parts, the research was so far limited to the planning and operational level (e.g. inventory or forecasting models). A review of the literature shows that strategic/design aspects have almost been neglected (Table 2).

2.2 Decisions on the planning and operational level

Due to the unpredictable and volatile demand for spare parts, inventory planning and demand forecasting for spare parts are quite challenging tasks for spare parts managers. Stocking too many spare parts leads to excessive or even obsolete inventories in the companies' warehouses, while under-stocking leads to unsatisfied customers. Both can torpedo the future revenues and profits of companies.

Table 1. Selected literature on supply chain management for primary products.

Level	Issues/supply chain decisions	Selected references
Strategy/design	<ul style="list-style-type: none"> ● Outsourcing ● Locations ● Long-term capacity planning ● Channels of distribution ● Supply chain type ● Modes of transportation ● Information and communication technologies 	Beamon (1998), Chauhan <i>et al.</i> (2004), Chopra (2003), Feitzinger and Lee (1997), Fisher (1997), Lee (2002, 2004), Meixell and Gargeya (2005), Olhager (2003), Reeve and Srinivasan (2005), Rodrigues <i>et al.</i> (2004), Wagner and Friedl (2007)
Planning and operations	<ul style="list-style-type: none"> ● Demand forecasting ● Service levels ● Short and medium term capacity planning ● Inventory levels 	Cachon (1999), Cachon and Fisher (2000), Konijnendijk (1991), Lee and Billington (1993), Musalem and Dekker (2005), Tibben-Lembke and Bassok (2005), Tyagi (2002), Zhao and Xie (2002)

Table 2. Selected literature on supply chain management for spare parts.

Level	Issues/supply chain decisions	Selected references
Strategy/design	<ul style="list-style-type: none"> ● Outsourcing ● Locations ● Channels of distribution ● Supply chain type ● Information and communication technologies 	Dennis and Kambil (2003), Huiskonen (2001)
Planning and operations	<ul style="list-style-type: none"> ● Demand forecasting ● Service levels ● Inventory levels 	Aronis <i>et al.</i> (2004), Ashayeri <i>et al.</i> (1996), Caglar <i>et al.</i> (2004), Chang <i>et al.</i> (2005), Cohen <i>et al.</i> (1989, 1990, 1999), Dekker <i>et al.</i> (1998), Diaz (2003), Fortuin (1980, 1981), Hollier (1980), Kalchschmidt <i>et al.</i> (2003), Kennedy <i>et al.</i> (2002), Liu and Lee (2007), Schultz (2004), Sleptchenko <i>et al.</i> (2005), Suomala <i>et al.</i> (2002, 2004), Thonemann <i>et al.</i> (2002), Wong <i>et al.</i> (2005)

In the past three decades, literature on the planning and operational level of spare parts in most cases has focused on the determination of the optimal inventory level for parts (Huiskonen 2001, Kennedy *et al.* 2002). Hollier noted that spare parts are an ‘important category of stocks for manufacturing companies’ (1980, p. 665). This importance of inventory planning has only increased, since the overall value of spare parts that an average manufacturing company holds on stock has soared in the last century (IIE Solutions 1996).

Inventory concepts and approaches, specifically designed for the spare parts business, have already been developed for simple repair shops (Scudder 1984), multi-hub systems (Wong *et al.* 2005), closed-loop supply chains (Fleischmann *et al.* 2003, Spengler and Schröter 2003), and to multi-echelon supply chains (Diaz 2003, Kalchschmidt *et al.* 2003, Caglar *et al.* 2004).

Case studies have been conducted in the computer industry (Cohen *et al.* 1990, Ashayeri *et al.* 1996, Thonemann *et al.* 2002), the airline industry (Tedone 1989), the metal industry (Suomala *et al.* 2002), the electronics industry (Cohen *et al.* 1999), power generation (Bailey and Helms 2007) and in the military (Rustenburg *et al.* 2001). These researchers applied general theoretical concepts to specific settings. Most of them applied mathematical or operations research methods (e.g. the Bayesian approach) to determine the optimum inventory level of spare parts (Aronis *et al.* 2004).

Some of the research that has investigated inventory concepts in manufacturing companies revealed a great discrepancy between theory and application. Ashayeri *et al.* (1996, p. 91) observed that ‘despite the wealth of literature on the subject, no attention has in practice been paid to proper management and control of service-parts inventory’.

2.3 Decisions on the strategy/design level

In contrast to the extensive body of knowledge on the planning and operational level, the body of literature on the strategy and design level seems to be limited to two articles.

Huiskonen (2001) focused on the logistics system design for spare parts. The author investigated the effect of four control characteristics of spare parts maintenance (criticality, specificity, demand pattern, and value of parts) and on logistics system elements (network structure, positioning of materials, responsibility of control, control principles). The most important characteristic of spare parts is the criticality factor,

the classification of spare parts according to their importance in the production process. Another objective of his research was ‘to emphasise the need to include the aspects of the whole supply chain in the analysis and to increase the collaboration between the parties at planning stages’ (Huiskonen 2001, p. 133). Despite the importance of Huiskonen’s approach it is still closely related to the investigations on the supply chain planning and operations level and therefore does not provide guidance for strategic/design decisions pertaining to spare parts management.

Dennis and Kambil (2003) also studied this gap in the spare parts management literature, analysing and discussing a few strategic concepts that selected companies already applied and giving some advice to the top management of industrial firms to build a ‘service-to-profit supply chain’. These supply chains require a ‘complex mix of materials, information, and service labour’ (Dennis and Kambil 2003, p. 46). These authors presented new strategies, infrastructure setups, and tools for companies to achieve ambitious goals in the spare parts business. Still, their analysis does not probe the actual challenges facing manufacturing companies, which are not ultimately best-in-class.

3. Research method

Due to the lack of research on strategic aspects of spare parts management, the case study method was chosen for this investigation. This in-depth study of a small number of selected companies is especially suited for exploratory research (e.g. Yin 1994, Voss *et al.* 2002).

In this study, spare parts intensive engineering companies with a strong reputation for their primary products (i.e. machines) were selected. Although there is no ideal sample size, six to 10 firms are recommended for this type of analysis (e.g. Eisenhardt 1989, Ellram 1996). To meet this benchmark, seven engineering companies were considered for this research (Table 3). All of the companies are headquartered in German-speaking countries but have operations around the world. All companies operate in intensely competitive environments with high rates of technological change. Most of the companies are world market leaders for their products. All of them position themselves as technology-based firms that provide high quality products and innovative customer solutions. The companies range in size from 70 to 5314 employees with an average of 1119 employees. Annual sales revenues range from €12 million to €1481 million with an average of €299 million.

Table 3. Overview of case study firms.

Company	Industry	Country	Total number employees	Total revenues (million €)
A	Engineering	Switzerland	90	18
B	Engineering	Switzerland	70	12
C	Engineering	Germany	120	20
D	Engineering	Germany	1681	410
E	Plant Engineering	Austria	5314	1481
F	Engineering	Germany	430	75
G	Package/Engineering	Switzerland	127	77

The spare parts managers were contacted via telephone and asked several questions about their involvement and insight into the spare parts processes of their company, in order to verify their suitability as key informants. Within an eight-week timeframe, one of the principal investigators visited each firm in order to conduct on-site case study interviews and collect supplemental data. In addition to the pre-identified key informant, additional employees who were involved in their firms' spare parts business were interviewed. This provided a broader insight into the particulars of the company and minimised the problems resulting from common source bias.

A comprehensive research framework and an interview guideline were developed in order to provide guidance for the case study interviews. The research framework is based on a literature review (see literature section above) and recommendations from several spare parts experts. The framework reflects several important strategic aspects of spare parts supply chains, i.e. the characteristics of the spare parts business, applied spare parts strategy, spare parts procurement and manufacturing, spare parts logistics and distribution as well as spare parts marketing and sales. Additional questions investigated the spare parts management accounting systems and the embedding of the spare parts business in the companies' organisational structure. All questions were open-ended. The framework and the interview guideline were sent out to the key informants between the initial phone call and the on-site interview.

Throughout the interview, additional topics of interest raised by the interviewees were discussed. The researcher wrote down all answers and transcribed them within 24 hours of the interview. To improve the validity of the findings, a copy of the documentation and results was sent to the interviewees, asking them to indicate whether they agreed with the findings. None of the interviewees requested any changes.

Besides the case study interviews, the researchers reviewed a number of published, but mostly internal, documents from the case study firms. This second source of data included annual reports, product descriptions, strategy papers, controlling reports, process descriptions, and project documentations. The broad range of documentary evidence and interview data presented alternative views of the firms' spare parts supply chains, management strategies, and processes. Throughout the research, the researchers triangulated and complemented the evidence gathered from multiple interviews and documents.

4. Research findings

4.1 Foundations of strategic spare parts management

The share of a company's spare parts revenues is one objective indicator for the 'strategic relevance' of its entire spare parts business (Dennis and Kambil 2003, Cohen 2005). On average the case study firms generate 13.3% of their revenues from the sale of spare parts, ranging from 3.2 to 35% (Table 4). As the spare parts revenues in the present study do not include additional or related after-sales services, the average revenue share of 13.3% is slightly lower than the percentages revealed in two recent studies (Dennis and Kambil 2003, Cohen 2005). The substantial share of revenues generated from spare parts sales underlines the strategic relevance of professional spare parts management for all of the case study companies.

Another objective indicator for strategic relevance is the profit contribution from spare parts sales. While none of the managers interviewed was able to pinpoint the profit contribution based on company records, all of them estimated that the profit share of the spare parts sales was even higher than the revenue share. Thus, selling spare parts seems to be a highly attractive and lucrative business for all case study firms. This finding is in line with Cohen (2005) and

Table 4. Total revenues and spare parts revenues.

Company	Total revenues (€ million)	Spare parts revenues (€ million)	Spare parts revenues as percent of total revenues
A	18	6.3	35.0
B	12	1.6	13.3
C	20	4.0	20.0
D	410	40.0	9.8
E	1481	80.0	5.4
F	75	5.0	6.7
G	77	2.5	3.2
Average	299	19.9	13.3

Dennis and Kambil (2003). The profit margins of spare parts sales in the automotive industry, for example, are three to four times higher than the margins in car sales (Dennis and Kambil 2003). Hence, in some of the case study firms primary products (i.e. machines) are sold for a price that is close to the cost of production, with the aim of stimulating future demand for spare parts.

We also urged the informants to provide a subjective assessment of the strategic relevance of their firms' spare parts business. All spare parts managers except for one (Company G) considered the strategic relevance of the spare parts business for their company to be high. Company G generates most of its profits from the sale of packaging material; that is, the primary function of the machinery business is to support the revenue stream for packaging material. As a consequence, spare parts management in this case needs to ensure that the customers' packaging machines work to capacity. The spare parts manager of this company therefore referred to the spare parts business as 'a necessary evil'. In contrast to this exceptional case, all other companies in this study consider their spare parts business as the 'only possibility to survive on the market' (as stated by two of the interviewees).

'Top management awareness' is the priority given to a firm's spare parts business (including time and resources). Despite the high strategic relevance of the spare parts business for six out of seven companies, the spare parts managers indicated a general lack of awareness. Although top management's awareness of the spare parts business has not yet reached an appropriate level in most of the companies, all informants noted that it is gradually increasing. This is consistent with Cohen's findings that corporate executives are paying more attention to the spare parts business today than they were years ago because of

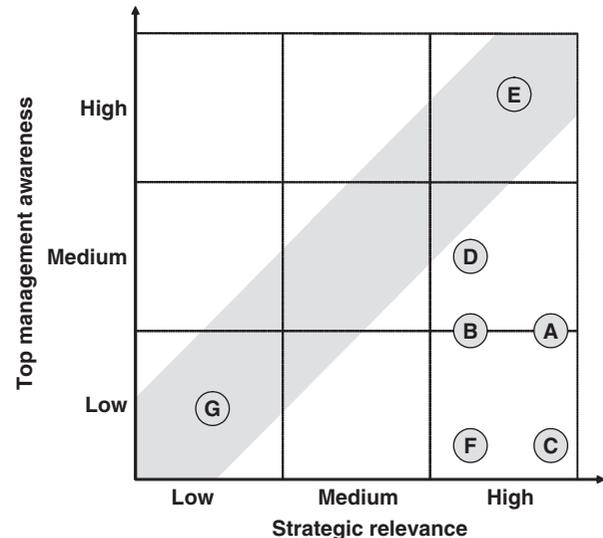


Figure 1. Strategic relevance of spare parts and top management awareness.

'immediate profit as well as longer-term customer satisfaction and new product revenue' (Cohen 2005).

In Figure 1 the current status of all firms is mapped along these two dimensions. Ideally, high strategic relevance accompanies high awareness from top management. Therefore, combinations outside the diagonal are deemed a mismatch and do not support an optimal exploitation of the spare parts business. This mapping reveals that only Companies G and E have a good match of top management awareness and strategic relevance. While Company E has ranked the spare parts business 'high on its top management's agenda for the last eight years,' Company G does not pay much attention to the spare parts business at all.

Considering the high strategic relevance of the spare parts business for the companies' success, it is surprising that only four of the seven spare parts managers have developed and are in the process of implementing an up-to-date spare parts strategy.

Two important determinants of the ability to exploit the spare parts business as intended by seven of the case study firms are (1) the installed base, and (2) the competitive situation. We will elaborate on these in the following paragraphs.

The installed base of manufacturing companies has been growing steadily in the past years; some authors identified an 'installed-base-to-new-product-ratio' of 13 to 1, with a clear upward trend for the future (Wise and Baumgartner 1999). However, most of the case study companies, regardless of their size, have only a 'cloudy view' of their current installed base. Because a great amount of product and customer data has not been entered into the companies' IT systems

(sometimes the data are only available in paper format, if at all), the specific number of and any additional information on primary products sold in the past cannot be determined. The spare parts manager of Company C stated in this regard that 'we are suffering from our insufficient data base'. To overcome this lack of information, some companies (e.g. Company D) determine their installed base by simple mathematical calculations. One example of such a calculation is the average number of primary products sold per year, multiplied by the average lifetime-age of the products in the field. These calculations are not sufficient to provide the required information on the installed base. Such a rough estimate includes precise information neither regarding the 'ageing schedules' of the products nor their current use (e.g. location, wear). An additional problem that was identified during the interviews is that products have been resold by the initial customers and therefore have changed their owner, thus rendering the 'first-time' customer information obsolete.

Despite some in-transparency on the spare parts market, the managers of engineering firms in our sample claim that the competition in spare parts sales is significantly lower than the market for their primary products. Overall, the companies included in this study do not face severe competition in their spare parts business. The informants remarked that some former employees may copy spare parts using technical documentations from their former employer and some customers may manufacture their own spare parts; but the spare parts managers 'are not really frightened by them' (manager of Company B). The low competition on the spare parts market explains the high profit margins that are achieved in this business area. The situation of low competition in the engineering industry might not hold in other industries. In the automotive industry, for example, competition in the spare parts business is quite intense (Ihde *et al.* 1999).

4.2 Outsourcing of supply chain processes

The outsourcing of supply chain processes can offer several advantages for manufacturing companies and for spare parts supply chains. In addition to reducing costs, outsourcing of spare parts supply chain processes can improve the efficiency of operations, and the quality and consistency of the delivery performance. Notwithstanding the immense body of knowledge on outsourcing (e.g. Gilley and Rasheed 2000, Leiblein 2003), outsourcing of specific spare parts processes has not received any research attention,

despite its popularity in corporate practice. Therefore, several spare parts processes, their degree of outsourcing, and the drivers and consequences of outsourcing are investigated in this study.

Physical distribution and transportation are two spare parts supply chain processes that companies frequently outsource (Ihde *et al.* 1999, Dennis and Kambil 2003). Since they do not consider transportation to be one of their core competences, all of the case study companies have outsourced the transportation of their spare parts to logistics service providers (LSPs). Outsourcing of transportation processes is fostered by the fact that third-party transportation costs have dropped significantly in the last years (Ihde *et al.* 1999), partially because of stronger competition on the logistics market. Despite some interviewees' concern, that this trend will probably reverse in the near future (e.g. due to rising fuel and insurance costs), their firms will not reverse their transportation outsourcing decision.

Companies A and B are currently planning to work with a large logistics company through an arrangement with a lead logistics provider (LLP). So far, the distribution and transportation of spare parts was managed by the companies' spare parts managers and incurred high process costs. Within the envisaged arrangement the LLP will be responsible for the selection and co-ordination of all LSPs. For each single spare parts shipment the LLP will select the optimal LSP in terms of quality, performance and price.

Company D has already outsourced its spare parts warehousing and Company G is planning to do so within the next six months of the interview. The reasons for the warehouse outsourcing decision that the managers mentioned were primarily the need for lower initial investments and secondarily the hope of decreasing variable operating costs provided by the LSPs.

The engineering companies in this study did not see any trend towards an increased outsourcing of spare parts supply chain processes as predicted by Dennis and Kambil (2003). Similarly, Fortuin and Martin (1999) show that only companies from the electronic industry, the automotive industry and airline operators tend to outsource spare parts supply chain processes. All of the companies investigated in our study operate exclusively in the engineering industry.

4.3 Spare parts inventory and procurement

The determination of inventory levels and spare parts procurement can either be managed separately from or

integrated into the supply chain processes of the company's primary products. In our research only two of the seven companies operate these spare parts processes separately; the other five companies decided to integrate them into the processes of the primary products.

Our case studies show that the inventory planning concepts discussed in the literature review are not intensively used in corporate practice. One reason for this finding, as our interviews revealed, is the difficulty of understanding and applying these theoretical concepts. Managers are only willing to use concepts they fully understand (Huiskonen 2001). Therefore, most of the companies involved in the study base their inventory forecasts and stock level determination on the data they had gathered in prior periods. Enterprise resource planning (ERP) systems (e.g. from SAP) provide special applications to support and facilitate these calculations. None of the firms we studied uses such inventory systems extensively, despite the fact that these systems are less sophisticated than the approaches presented in the academic literature. The spare parts manager of Company G even applies a variety of heuristic 'rules-of-thumb' for the spare parts inventory planning, which are surprisingly common and very popular in managerial practice (Huiskonen 2001).

Concerning the procurement of spare parts, the case studies show that all engineering companies use the same suppliers in their spare parts processes as in the primary product manufacturing processes and all of them have made efforts to reduce this supplier base in recent years.

4.4 Spare parts logistics and distribution

Similar to the distribution of primary products, the distribution of spare parts can be organised directly or indirectly. That is, spare parts can either be distributed to the final customers from one central warehouse, which is often located close to the manufacturing facilities, or indirectly via regional warehouses. Six out of seven companies in our study operate regional warehouses. Some of the companies have had problems shipping goods out of Switzerland at weekends when there are fewer customs officers on the Swiss border. Company A has had problems with the customs in Malaysia in the past. By installing and operating external distribution warehouses, the lead time for spare parts was significantly reduced and customer service levels were increased. Representatives of some of the companies stated that regional contact personnel could enhance customer satisfaction by

offering more specific information about the regional order processing or customer complaints. Only Company F serves all customers directly from its production plant in Germany. The reason for this set-up is that the spare parts manager tries to avoid keeping the same spare parts at multiple warehouses.

All of the case study companies have several service levels that they offer to their spare parts customers. For the most part, the service levels are identical with the transportation services offered by the LSPs. This is because transportation is outsourced at each company. In general, there are two standard service levels: 'Express' and 'Economy', the former is faster but the latter is cheaper. In order to satisfy the end customers, all of the companies seem to be heading towards a service philosophy that the manager of Company G called 'everything is possible'.

4.5 Spare parts marketing and sales

Because of the high profit margins that can be generated in the spare parts business, companies are willing to increase, and in some cases rely on increasing, their spare parts sales. One idea to increase future sales is to install and operate active spare parts marketing. As described above, due to insufficient databases, the companies are facing the central problem of not having an accurate sense of the owners of their primary products. This circumstance makes active spare parts marketing for older primary products almost impossible, since, as the manager of Company D stated, 'the fundamental issue of after sales is the quality of the database'.

Analyses and discussions of spare parts marketing approaches are also very scarce in the literature. There is only one related publication in a practitioners' journal. According to Peterson (1997), companies, especially those in the automotive industry, can boost their profits by marketing tailored spare parts.

Since the improvement of spare parts marketing is a rather demanding (and, in the case of an in-transparent installed base, almost an impossible) task, some of the case study firms have tried to improve the efficiency of their spare parts sales processes. One suggestion that has been made in recent years, and empowered by the internet, is the establishment of business-to-business 'spare parts online shops'. Companies thought that it would be just as easy to sell spare parts via the internet as it was for companies like Amazon.com to sell books. The considerations behind the idea are obvious, since benefits can be achieved on both sides. The customer's

order would be transferred directly to the ERP-system, triggering the internal order or production processes of the spare parts as well as logistics and distribution processes. Processing costs could be reduced and the customer would be rewarded with lower prices and faster delivery (Checketts and Patel 2006).

However, our study shows that this reasoning is difficult to translate into business practice. Companies A, B and E have invested substantial human and financial resources, but still receive far less than one percent of all orders via the internet (which a manager of Company E described as 'more than disappointing'). As a consequence, Company E has ceased offering this service since not even operating costs were recovered by efficiency savings. The spare parts managers attributed this failure to the IT incompatibility of their customers and their own company, the latent danger of erroneous orders, and the complicated internal order approval processes at the customer company. The idea of online purchasing for spare parts, which has been proclaimed to be an important success factor for companies (Checketts and Patel 2006), is still in its infancy and will probably still remain there for the foreseeable future.

4.6 Organisational embedding

Despite the high profit contribution of the spare parts business to the overall performance of the companies, only one spare parts manager (at Company E) is responsible for the profits of the spare parts division. Company E has the largest spare parts business of all case study companies, and this might explain the profit centre setup. Another reason might lie in the amount of attention that the top management of Company E pays to the spare parts business. In contrast, none of the other companies have their spare parts departments organised as profit centres. Similarly, Ihde *et al.* (1999) revealed that profit or cost centre structures for spare parts business are commonplace in the automotive industry, but not in other manufacturing industries as our results reveal for the engineering industry.

4.7 Management accounting for spare parts

To ensure efficient management for spare parts, companies might introduce management accounting practices that focus on their spare parts business. We have learnt from our case studies that a dedicated spare parts management accounting does not exist at any of the companies. Although, there are some key spare parts performance indicators such as 'number of

orders', 'spare parts inventory turns', or 'relationship between offers and orders' that are calculated and controlled in some companies (as in Company C), there is no systematic approach to these spare parts processes. In most cases the companies solely rely on top level financial figures, i.e. the revenues from spare parts sales.

5. Implications

For decades, managers have thought of spare parts as nothing more than a necessary service that a firm has to provide to keep its customers satisfied. In order to ensure the availability of spare parts at low cost, companies focused on holding the 'optimal' level of spare parts inventories in their warehouses. The objective was either to provide a given availability at the lowest possible cost or, inversely, to provide maximum availability at given costs. All efforts in corporate practice (and for a long time also in research) pointed in this direction. Other process optimisation approaches were neglected since the spare parts business generated substantial profits for the companies even in the absence of effective and efficient spare parts supply chains.

Throughout this research, we were able to identify the key areas that engineering companies should focus on in order to capture the revenue and profit potential of the spare parts business and identify the managerial implications. Likewise, some implications will assist the scientific community in supporting corporate practice in its spare parts SCM. The most important implications are summarised below.

Improving inventory planning. The level of spare parts inventory also determines the responsiveness and a substantial portion of spare parts supply chain costs. Although there is a huge body of academic literature on theoretical inventory planning concepts for various spare parts supply chain settings, few companies seem to apply them rigorously. First, the spare parts requirements of the engineering firms' customers (e.g. spare parts of construction equipment) are very volatile. The demand for spare parts is often determined by the level of machine utilisation. With irregular machine running times (especially in project industries) it is very difficult to apply forecasting and planning tools. Second, these models are either too specific or too complicated for adoption in corporate practice. Therefore, concept development for inventory planning of spare parts should concentrate more on its applicability in manufacturing companies. At the same

time the firms should prepare for and be more open to the adoption of spare parts inventory planning systems.

Utilising the capabilities of LSPs. In addition to standard processes (i.e. transportation), LSPs might take the more responsible role of an LLP and provide co-ordination services for their customers. Manufacturing companies can use the specific industry knowledge, expertise and the purchasing power of global logistics companies to improve the quality and cost-efficiency of spare parts logistics and distribution. Especially small engineering companies with customers and demand for spare parts all over the world do not have the resources to co-ordinate their distribution activities as efficiently as LLPs.

Knowledge enhancement of installed base. The first step of any attempt to optimise spare parts management is to enhance the knowledge of the installed base, including but not limited to customer information and primary product wear and tear. This is particularly important for engineering firms with small-scale production (e.g. heavy equipment). Related customer and product documentation that are only available in paper format should be entered into electronic databases and managed through intelligent spare parts software systems. Furthermore, installed base information that is already available electronically requires regular updating and completion.

With the exact knowledge of the installed base and all customer data, spare parts management can be advanced in several ways. The spare parts inventory planning can be improved by more accurate demand forecasting. The problem of obsolete stock will not occur, since inventory will be manufactured and kept in stock only for machines that are still operational; product lifecycle planning will therefore be amended. Further, the knowledge of customer data is essential for the kind of active spare parts marketing that some companies already have on their agenda.

Formulating and communicating spare parts strategies. Formulating spare parts strategies is necessary to determine the direction in which the company's spare parts business is heading. The spare parts strategies should therefore include at a minimum the aspects we have addressed in this article; e.g. it has to be decided on the basis of the desired revenue and profit contribution of the spare parts as well as on certain measures and levers like the amount of marketing activities. All tactical and operational actions and processes need to be aligned with the overall spare parts strategy. The strategy has to be communicated to

all actors involved in the companies' spare parts processes.

Increasing top management awareness. Changes and improvements in spare parts management can only be initiated and succeed with the support of the top management of the company. Our study shows that there is still a severe lack of top management awareness in the engineering companies. Top managers will ask for performance indicators and performance measurement systems, so firms need to establish and develop management accounting and performance measurement systems for their spare parts business.

6. Conclusion

In this research project we investigated the strategic aspects of spare parts management in the engineering industry. The firms we studied have had tremendous difficulty exploiting the significant revenue and profit potential inherent in their spare parts business. Through more professional spare parts supply chains, the firms would be able to compensate for the shrinking margins of their primary products. In sum, our research revealed that there is still a lack of strategic SCM approaches tailored to engineering firms' spare parts business. We have identified some approaches in our research and presented recommendations in this article.

Our results are subject to some limitations. Besides the general restrictions and limitations of the case study research approach (e.g. Voss *et al.* 2002), our sample only includes engineering firms and companies located in German-speaking countries. Therefore all findings and implications cannot be readily generalised to other industries or other countries. Other industries, such as the automotive industry, might have already achieved a higher level of professionalism in their spare parts management strategies and supply chains. As we have done in this research, future studies on spare parts businesses and supply chains should focus on a single industry at a time in order to explain industry peculiarities.

Notes on contributors



Stephan M. Wagner is a full Professor and holds the Chair of Logistics Management at the Swiss Federal Institute of Technology Zurich. He previously served on the faculty of WHU – Otto Beisheim School of Management, and worked for 10 years as head of supply chain

management for a Swiss-based technology group and as senior manager for an international top-management consulting firm. He obtained his MBA from Washington State University and PhD and Habilitation degrees from the University of St Gallen. His research interests include supply chain strategy, purchasing and supply management, inter-firm relationships in industrial marketing channels, innovation in supply chains, and the management of logistics service firms. He is author and editor of eight books and over hundred book chapters and articles.



Eckhard Lindemann is a research assistant and doctoral candidate at the Kuehne Foundation Endowed Chair of Logistics Management at WHU – Otto Beisheim School of Management, Vallendar, Germany. He graduated in business administration from the Ludwig-Maximilians-University Munich, where he focused on logistics, supply chain

management, and empirical research methods. He gained practical experience through several internships with industrial and service firms as well as consulting projects in industrial firms. Before joining WHU he worked as a research assistant on a large, EU-sponsored research project related to logistics in the European automotive industry. His current research interests focus on the management of supply chain relationships.

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